DIGEST OF INDUSTRIAL AND TECHNICAL DEVELOPMENTS

Chemical Industry in Europe

AFTER a slightly slower rate of expansion in 1956, chemical production in member countries of O.E.E.C. increased by 10% in 1957, whereas total industrial production increased by 5%. For the whole of 1958 the indications are that chemical production will again increase, but most probably more slowly than 1957. For instance, chemical production in the first six months of 1958 was 6% greater than in the first six months of 1957, the corresponding figure for total industrial production being 3%. As in recent years, the sectors expanding most rapidly are petroleum chemicals, plastics and nitrogenous fertilisers. Investment in the chemical industry in 1957 is estimated to have been $1000 million, which is some 7% above the 1956 figure. The classification for chemical and allied trades used by the Central Statistical Office for Britain is slightly different from that used by O.E.E.C., but not sufficiently to invalidate comparison. On the basis of 1948 as 100, the index of industrial production for these trades was 185 in 1956 and 192 in 1957. After some earlier fluctuation the figure returned to this level in June, 1958. This is certainly a much better picture than the general one for all manufacturing industries (on the same basis 1956=140, 1957=143, June, 1958=138), but makes a poor showing compared with the rest of Western Europe. A report of the last F.B.I. enquiry issued in mid-October concludes that there has been a marked change in the attitude towards the general business situation; there is a reversal of the pessimistic attitude reported in an earlier enquiry. In the current survey 35% were more optimistic and 17% less optimistic than they were in June. In June only 19% were more optimistic than they were in February; 31% were less optimistic. The report adds that the comparative stability of the rate at which new orders are being received supports the general impression that there will be a levelling off in the decline of activity in the next few months. There is even a possibility of a slight upturn. It is understood that chemical and allied trades were above average both in their assessment of the future and in their reports of recent business activity. The chemical *plant* industry tends to follow general industrial trends but with a considerable time-lag. Its position is difficult to assess because there are no separate statistics for this branch of engineering.

Performance of Condenser and Heat Exchanger Tubes

AN up-to-date survey by P. T. GILBERT of the factors affecting the corrosion and the performance of tubes used in condensers and heat exchangers including useful advice on selection of materials was presented before the Society of Chemical Industry. For example a practical tip on combating corrosion by cooling water is that an arbitrary division can be made at a total dissolved solids content in the water of about 2,000 p.p.m. If the water contains more dissolved matter than this for an appreciable proportion of the running time, it is advisable to use aluminium, brass or a cupro-nickel alloy because of the risk of impingement attack on copper or the ordinary brasses. General experience is that in polluted waters the cupro-nickel alloys give the best results; sometimes the 70/30 alloy is rather better than the 90/10 and in other cases the reverse applies. Much can be done to minimise the effect of polluted water. The most promising measure suggests DR. GILBERT is the Taprogge system (B.P. 700,833) of continuous and automatic cleaning by circulating soft sponge rubber balls. This removes scales and deposit thus removing the conditions under which pitting occurs.

Many other corrosion problems including those in refineries were also discussed in the paper. In the treatment of operational performance it would have been helpful to have seen some representative figures for heat transfer and for velocity distribution to back up the generalisations such as those on the value of uniformity of conditions throughout the tube bundle. However it was interesting to have the comment that one of the biggest mistakes in the design of tubular condensers and heat exchangers is to use too many tubes. In many instances equipment has been found to work more efficiently after an appreciable proportion of the tubes have been removed.

Uranium Extraction by Organic Solvents

SOLVENT extraction methods are being developed at the National Chemical Laboratory for removing uranium both from sulphuric acid leach liquors and from leached ores. The same solvent—a 0.1M solution of di-(2-ethylhexyl) hydrogen phosphate in kerosene—is used in the two cases. Only the detailed technique for contacting the phases is different. For selective concentration of uranium from clarified sulphuric acid leach liquor, solvent extraction offers the advantages of continuous counter-current operation, greater flexibility to cope with changes in the feed, freedom from poisoning and mechanical blockage problems that are experienced with ion-exchange, and a smaller capital expenditure on plant. Against this must be reckoned the loss of solvent to the aqueous phase by solubility, entrainment and possibly chemical degradation; this loss will be the chief factor controlling operating costs. Extraction is carried out in a multi-stage mixer-settler apparatus. Leach liquor and solvent are intimately mingled in the mixer and uranium passes into the solvent phase; the mixed phases flow into a settler where they separate out, and then move countercurrently into the mixer of the adjoining stage. The solvent becomes loaded with uranium and passes to the stripping section, comprising more mixer-settler units, where it is relieved of its uranium by contact with a stripping solution, such as acidified molar sodium chloride. From this, the uranium is precipitated by the addition of ammonia or magnesia. The recovered solvent is returned to the extraction circuit. In treating ores

already leached with sulphuric acid the pulp and solvent are pumped countercurrently to one another through a disc contactor unit, which consists of a cylindrical vessel in which rotate a number of discs on a central shaft. The discs are interleaved with stationary separators to reduce short-circuiting of the solvent and aqueous phases. As the discs rotate a film of the aqueous solution is carried through the solvent, so effecting transfer of uranium. Filtration of the pulp is eliminated. We understand that this process is considered to be at too early a stage to make it possible to estimate costs.

Pre-stressed Concrete for Plant Structures?

PERSUASIVE advocate for the wider use of pre-stressed concrete in the construction of refineries and petrochemical plants is JOHN MAKARETZ, writing in *The Petroleum Refiner**. So far the main use in the petroleum industry has been in precast oil storage facilities. MR. MAKARETZ now discusses techniques and costs of using pre-stressed concrete piles for foundations, beams and columns for pipe supports, and structural members for buildings. Although the account points out that tensioning the reinforcing steel results in saving material and—the aesthetic touch—producing slender, pleasing structures, this is no uncritical gush. It is noted that from about 380°F upward, a pre-stressed member loses its pre-stressing and becomes an ordinary concrete member with highly stressed, untensioned reinforcement. To avoid heat damage, pre-stressed steel should have a substantial insulating cover or an additional layer of fire-resistant material. This suggests that in fire hazardous areas, use of conventional reinforcing concrete or, in some cases, fire-proofed steel is more economical and technically more sound. In general, pre-stressed members are most economical where standard sizes can be used, or where adequate repetition occurs to justify special sizes.

On page 681 of our present issue there is a report of an attempt to use lined tanks of pre-stressed concrete in Britain for sea-water storage.

* 1958, 37, No. 9, p.343.

Surveys of Catalysis

IS there a unitary theory of catalysis? Enormous strides have occurred during the last two decades in applying this method of altering the rate of chemical reactions. The first industrial uses in the middle of the eighteenth century were in the field of inorganic preparations. Later there was development in organic chemicals and then a third group of processes in the production of fuels. All of this ground is ably covered by G. A. MILLS in a recent paper* which goes on to review recent examples of catalytic chemistry and briefly discuss theory. While no one mechanism of catalysis fits all catalysts, it now appears possible to correlate their action according to some classification, namely (a) acid-base and (b) electronic defect. What makes it difficult to generalise is that the specific individual properties of catalyst substances do enter and must be considered. For example, palladium sulphide is stable whereas platinum sulphate is reduced to metal under usual petroleum reforming conditions. For this reason, in this instance palladium is relatively inactive catalytically while platinum is active. A multiplicity of reactions occur in the catalytic cracking of hydrocarbons including scission, cyclisation, isomerisation, hydrogen transfer, and others. From catalytic cracking of a straight-chain paraffin such as cetane products are characteristically iso-paraffins, olefins and aromatics. It is these components which make them so valuable for high octane gasoline. The products of catalytic cracking have been accounted for with a high degree of success by application of carbonium ion theory. Catalysts for these hydrocarbon reactions are thought to act because of their essential acidity. But catalysts of a second class are active because of properties other than their acid-base properties. Such catalysts are especially effective in oxidation and in hydrogenation-de-hydrogenation. A significant advance stems from the recent development of dual function catalysts. Such a catalyst, employed in petroleum reforming, contains both an acid (derived from alumina) and a metal (platinum). More complex reactions are possible, with two types of catalytic functions.

Earlier this year a conference on the physics and physical chemistry of catalysis in Moscow attracted a large number of papers which have been reviewed by C. Z. ROGINSKII in *Khimicheskaya Nauka i Promishlyennost*, 1958, 3, No. 4, p.522. Subject matter included the use of semi-conductors, metals, acid-base catalysis, and general questions of theory.

* *Chemistry in Canada*, 1958, 10, No.9, p.39

Thermal Diffusion Plant for Concentrating Helium 3

AT A.E.R.E., Harwell, a thermal diffusion plant for concentrating the rare isotope Helium 3 from atmospheric helium has been operating since 1950. In this time several thousand cubic feet of helium have been processed producing more than 100 cc NTP of He^3 at concentrations up to 10% He^3/He. Design was based upon the theory of JONES and FURRY[1]. The plant consisted of three 15 ft. metal columns mounted vertically side-by-side and linked in series by convection tubes. The columns were a coaxial-tube column to "scrub" the incoming atmospheric helium of its He^3 and two enrichment columns, one a coaxial-tube type identical to the scrubber and the other a hot-wire column. Under the most economical operating conditions, the cost of production was a little less than £50 per cc NTP of He^3.

In the course of the work an expression for the theoretical variation of stripping efficiency with pressure and flow rate has been derived, the stripping-efficiency being defined as the ratio of the He^3 concentrated to the total quantity entering the system. At constant flow rate, there is qualitative agreement between the theoretical and experimental results, and it was considered that the expression is sufficiently accurate to be used for design purposes in order to decide roughly at what pressure the plant should be run. Enquiries about the relevant report[2] should be addressed to the Scientific Administration Office at Harwell.

1. *Review Modern Physics*, 1546, 18, p.151
2. A.E.R.E. GP/R 2058.

How Much Oil — When?

THIS was the heading of a "do it yourself" procedure for estimating oil production at any time in the future, which was given to the London Branch of the Institute of Petroleum recently by PROF. E. S. SELLERS in a talk entitled "The Petroleum Industry in the year 2000 A.D." It was argued that the present pattern of expanding production could be expected to go on at some compound interest rate, but that in the not two distant future the industry would reach its final maximum production rate, after which there would be a slow decline. During this "falling rate" period, the output every year would be a

function of how much oil there was left. Estimates have been made of the total reserves of recoverable oil, and two were quoted. The first was due to LEES and ION in 1952, and was based on an estimate of the total area of sedimentary formations which were "potentially petroliferous." This gave an ultimate total production outside Russia of 70 thousand million tons. The second estimate, given in 1956 by WALLACE E. PRATT to a U.S. Congressional Committee, was that the ultimate reserves which could be extracted at a real cost up to double the present cost were 117 thousand million tons. As an example of his suggested procedure, PROF. SELLERS worked out that if the production rate increased at 5 % per annum for 28 years it would then be 3.9 times the present rate. During the "falling rate" period—assuming a first order chemical reaction kind of expression, where every year a constant fraction of what was left was extracted—the required production rate in the year 2000 A.D. was estimated as three-quarters of what it is now if LEES' estimate was right, but twice what it is now if PRATT was right.

To maintain the expected production rate PROF. SELLERS examined the probable future investment pattern in the industry. It was likely that the proportion expended on exploration and crude oil production would continue to grow, and processes for the manufacture of liquid fuels from shale, tar sands and natural gas could be expected. The uses of computers in linear programming techniques for the planning of refinery operations, and for the control of refinery processes was described, and there was some mention of the work being done at N.P.L. and elsewhere on "learning machines" and their possible application to the control of process plant.

Studying Human Beings in Industry

WORK on the human sciences in industry may well contribute greatly to both productivity and industrial peace but it is difficult to assess this from the two associated reports* now published jointly by the Department of Scientific and Industrial Research and the Medical Research Council. Vagueness abounds. It is evident that the purpose is to sketch the general picture and draw attention to individual research for detail. But even at this level of treatment occasional detail would have made points more strongly than relying on notes such as this—"performance of girls completing organised training considerably exceeded management's expectations or previous experience of a school-leaver's capacity in output, quality or scope." By how much? What is the economic balance against training costs?

The final report of the Committee on Human Relations in Industry aims to review the research which they have sponsored and to indicate the lessons which have been drawn from their experience. A number of projects of undoubted value are listed. Yet it is difficult to see what lessons are drawn. The Committee recognises that individual firms participating in particular studies may reasonably expect the research to suggest certain specific courses of action. They comment that since human situations are so complex, and are governed by so many different factors, the suggestions may not be valid for the wide audience of firms to which the results will be addressed. What, then, can interested firms, unions or individuals expect that will be of use to them? The report states that research workers in this field believe it is information that will enable them to compare their own experience with that of others; data about human reactions to the work situation that can only be obtained through systematic and careful observation; and the formulation and interpretation of problems in such a way as to stimulate fresh thought in industry. But the effort to translate such information and interpretation into specific lines of action is referred back to management and trade unions themselves. This approach is evidently reasonable if the work provides results capable of being used in this way.

* "Human Relations in Industry 1954-57."; Individual Efficiency in Industry 1953-57." H.M.S.O. 3s. 1958.

Resistance Thermometer for Low Temperatures

GERMANIUM can be doped with arsenic to produce an element with a high and fairly constant temperature co-efficient of resistance at temperatures near the boiling point of helium. Both the temperature coefficient and the resistance vary widely with minute changes in the amount of doping, making it possible to fabricate a thermometer having any of a wide range of characteristics. Resistance thermometers constructed on these principles by the Bell Telephone Laboratories have been sent to the (U.S.) Calorimetry Conference for testing. They are said to retain the calibration to better than a few thousandths of a degree at the boiling point of helium (4.2°K) despite repeated cycling from 300°K to 1°K. A typical thermometer had a resistance of about one ohm at room temperature, 14 ohms at 10°K and 216 ohms at 2°K.

The heart of this thermometer is a "bridge" of about 0.025 in. x 0.020 in. x 0.210 in. cut from a single crystal of arsenic-doped germanium. Current and potential leads are attached to the bridge, and it is supported in a strain-free manner in a platinum-glass enclosure containing a small amount of helium gas to aid in thermal conduction. The resistance is determined by measuring the potential drop when a known current of about 10 microamperes is passed through the bridge.

Masticating Rubber

SOFTENING of rubber during mastication is now considered to be a consequence of the breaking of molecules by the applied shearing forces. The mechanical treatment literally tears the rubber molecules apart into fragments with free radical ends of high chemical reactivity—hence the description "mechanico-chemical" for the overall process. This recognition of the fundamental principles of milling and mastication, which have been basic processes in the rubber industry from its earliest days, means that much well-established empirical practice can be rationally appraised and opens up new possibilities for chemically modifying the rubber. But this kind of degradation is not limited to natural and synthetic rubbers or even to substances which would normally be described as rubber. Such diverse materials as common plastics (polythene, polystyrene, polymethyl methacrylate), polycondensates (nylon, phenolformaldehyde resins), natural proteins and carbohydrate polymers (casein, starch, sugar) and modified natural polymers (rayon and ethyl cellulose) all behave in this way, and in doing so display quite novel chemical reactivity.

A summary of this work appears in the current Annual Report of the British Rubber Producers Research Association. With it appear notes on laboratory machines designed to investigate the two distinct processes taking place in internal mixers. One, physical in nature, is a dispersing of one compound among another; the other, essentially chemical, is the tearing apart of polymer molecules. It is evidently now becoming possible to consider whether the

first or second of these processes, which are conveniently specified as "mixing" and "masticating" respectively, is primarily required in any given operation.

Packing and Flow of Spheres

IN heat- and/or mass-transfer systems where the transfer takes place between a stationary bed of randomly packed spherical particles and a fluid flowing through the bed, the surface transfer coefficients and the pressure loss of the fluid are all sensitive to the voidage (or density of packing) of the bed. In a recently released paper*, W. H. DENTON of Harwell reports experimental measurements of the stability of the voidage. The experimental bed consisted of size-graded marbles of about 0.2 in. diameter. For a cylindrical container with hemispherical base and diameter equal to 42 sphere diameters, a most probable value of 39.1% voidage was obtained when charging by hand; the standard deviation of the measured overall voidage was 0.16%. For a simple mechanical charger this standard deviation was 0.10% voidage about a most probable value of 39.4%. Under conditions of intermittent discharging of the bed under gravity while recharging on to its upper surface, the standard deviation (when the bed was stationary) decreased to 0.04% voidage about a most probable overall voidage of 39.5%. Repeated vibrations and jolts were not able to reduce the overall voidage (when stationary) below about 36%. By measuring the voidage at the walls of the bed, the characteristic voidage excluding wall effects was estimated to be 35% ± 0.8% standard error.

Experiments on the flow patterns of spheres, when intermittently discharging the bed under gravity and recharging on to its upper surface showed that individual spheres followed consistent flow paths. For a right cylindrical container with a conical base and small outlet orifice, there were no "stagnant" regions in the base and the ratio of the total times of transit through the bed of those marbles at the wall and those at the centre of the bed was approximately 1.9%. Fairly smooth glass spheres and a perspex container were used so that friction effects were small.

*A.E.R.E. E/R 1095.

Teaching the Teachers of Mathematics

THANKS to the courtesy of PROF. H. BEHNKE, President of the International Commission of Mathematical Instruction, we have had an opportunity of seeing contents page proofs of an important document* in the development of the commission's work. Sound training in mathematics in the secondary school lies at the root of successful practice in scientific engineering at a later stage. Recognising the importance of this concept, the International Commission in 1954 set itself the task of reconsidering the scientific basis of school mathematics in order to guide teachers. The German sub-committee have now completed a volume opening with a section on the fundamentals of mathematics, then dealing with arithmetic and algebra. Each article has two authors. One is a professor and the other a present or former schoolteacher. It was hoped that this combination would produce the desired balance in the treatment of the subject. As the teams got to work they found that they had evolved material which they thought useful for both teachers in secondary schools and for practising mathematicians, whose services are now so widely used in industry. This unique collective creation covers such subjects as linear algebra, polynomials, complex numbers and quaternions. Three following volumes are due to deal respectively with geometry, analysis, and practical methods and applications of mathematics. For the moment it is intended only to publish in German and there are no immediate plans to follow up with a direct school text book. At a recent conference of the commission when this was reported, a paper was also presented by PROF. FEHR of Columbia University on the "mathematics education" of youths up to the age of 15 years. In this it was suggested that all over the world the subject is overloaded with "doing" and it would appear that a reformation of this programme with emphasis on "reasoning" and an elimination of much useless and extraneous busy work could enliven the subject. This would leave the 15 year old with a much clearer and stronger picture of what mathematics study really is.

* Grundzüge der Mathematik. Band I. Grundlagen der Mathematik. Arithmetik und Algebra. Göttingen. Vandenhoeck & Ruprecht, 1958.

Convention with a Difference

THE Scientific Instrument Manufacturers Association has been holding a convention of a new kind. Rather than arranging set papers in which learned contributors harangue the hearers they have had only short introductory statements and have invited instument users to put forward criticisms and comments. MR. BARRINGTON BROCK, Sima President, stressed that most instrumentation is quite specialist in character so that any instrument intended for more than one application is the result of compromise between varying demands of specialists in a number of industries. Sometimes there have been damaging remarks by eminent users about the quality of British instruments. On investigation they have often proved to be unjustified as a general comment. The complaint has usually arisen from annoyance over one difficulty on one instrument.

A strange fact revealed by the President was that the new embargo list on trade with Russia had been drawn up by the Board of Trade without consultation with Sima. After examining it most of their members had said there was practically no change as far as their possibilities of trade were concerned. Sima was now approaching overseas comparable associations for a general approach to several governments in concert since any decision here would of course only be given after consultation with other interested governments.

Identifying Defects in Aluminium Welds

MANY more defects can exist in aluminium alloy work than in mild steel, mainly because these alloys can be fabricated by several different processes. A collection* of radiographs of defects which can occur in aluminium welds will therefore be of great value to fabricators. Defects are classified, their origin explained and suggestions made for their prevention. The examples given are radiographs of arc welds, mainly of the tungsten-arc or self-adjusting arc types. Defects found fall naturally into five principal groups: cracks, lack of fusion, voids, inclusions and imperfect shape. Radiographs of aluminium welds illustrating the various types of defect within these five categories have been selected as representative and clear examples often accompanied by diagrams. In respect of porosity, it has been possible to list various grades of severity and relate these, in a general way, to tensile efficiency. Cracks and lack of fusion undoubtedly cause the most damage to tensile efficiency but their effects are variable and can only be correlated qualitatively with strength. To assist in the recording of defects, suggested abbreviations for the various categories are given.

* "Classified Radiographs for Defects in Aluminium Fusion Welds." Prepared by P. T. Houldcroft, J. G. Young and A. A. Smith. British Welding Research Association H3/58. 10s.

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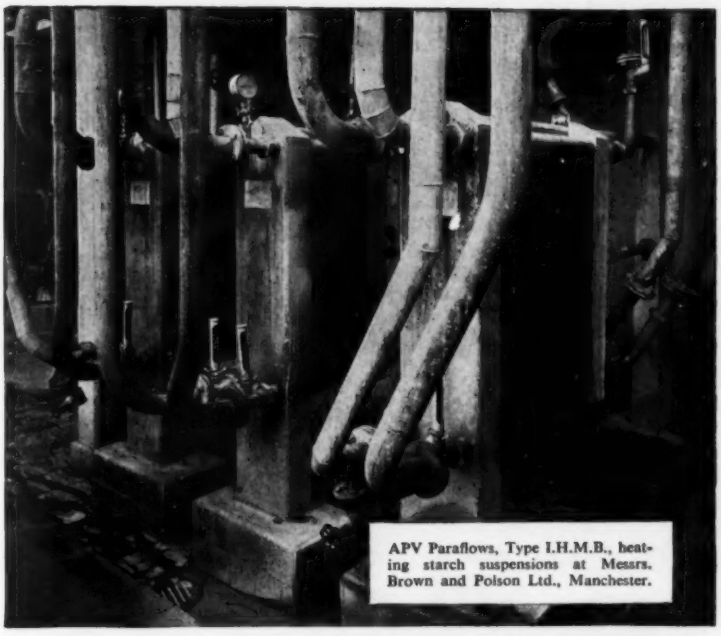

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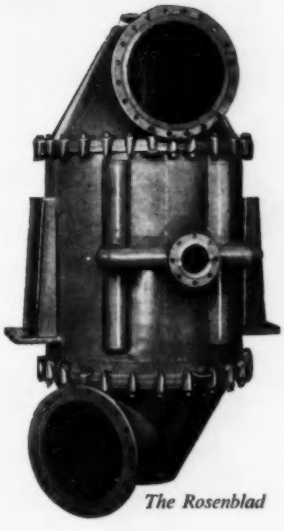

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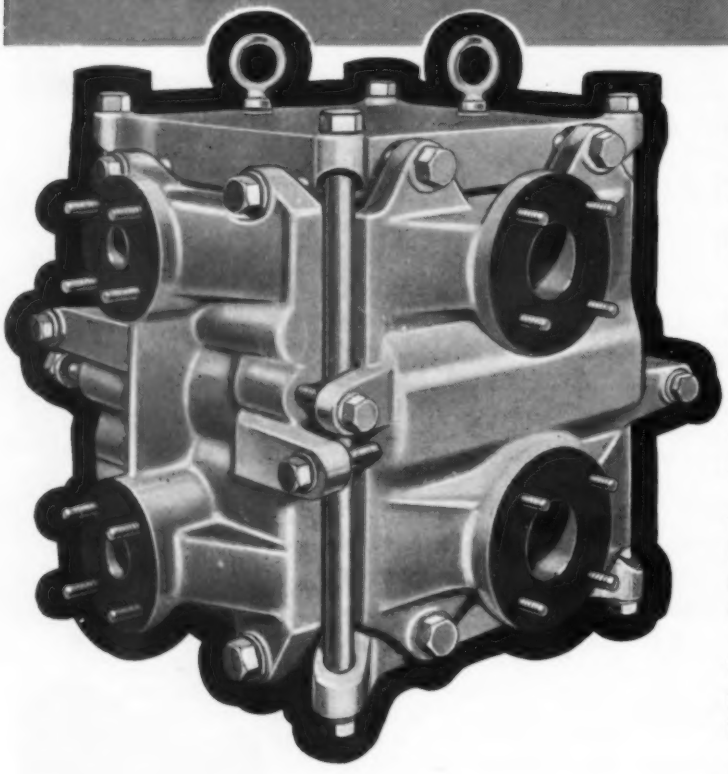
Heat exchanger standardisation



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Forward from "Guestimation"

"AN engineer is a man who can do for one pound what any fool can do for two." With this striking thought, DR. R. EDGEWORTH JOHNSTONE brought to a close the impressive pioneering conference in chemical engineering economics organised by the younger brethren—the Graduates and Students Section of the Institution of Chemical Engineers. The high spots of this conference were lofty indeed. Cost data were disgorged in a way which many had previously thought un-English. Yet detailed figures were disclosed for process instrumentation, automatic-control equipment, process vessels, heat exchangers and pumps and fans. To round off the picture, MR. STAINTON, of the National Industrial Fuel Efficiency Service, reminded us of the value of thermal insulation and backed his thesis with firm figures.

Only in one detail was the happy pattern of frankness marred. Notional figures given in one case were shown in discussion to deviate appreciably from practical experience. After they had been queried, the speaker admitted their hypothetical character and gave a reference to a source of practical figures based on American experience. But this was only one lapse. For the rest, and despite the querying of some prices by plant suppliers, one could hear general approbation from the body of the hall as figures poured forth, and an engineer here confirmed detail which he knew well, while another there testified to the accuracy of other material where the ground was familiar. Never was there such furious note-taking; never before such attentive listeners. The student absorbing fresh information, the experienced engineer anxious to check against his own records were both equally anxious to miss nothing.

Are we now in the way to a more rational approach to the release of cost information? Hitherto the fog has been so thick that DR. EDGEWORTH JOHNSTONE described his notebook of cost data—gathered continuously at every opportunity—as the most precious document in his technical library. He advised graduates to go forth and gather data likewise—bearing in mind always to book date with data. Part of the material of this symposium is summarised in our present issue and we hope to present a further report later. Even with this fresh material, however, estimation of complete project costs is still very empirical. The various devices which we have reported are mainly pointers to methods of rationalising the individual engineer's experience. Most engineers are limited to their own experience and what are usually considered the necessary limitations of commercial secrecy, a category almost more severe than its military counterpart. Because of this, internal first estimates tend to be rather personal and the name on the covering memorandum may also imply a particular approach which differs from that of another worker. The fresh wind from this conference has certainly started to reduce the murk. In addition, some sectional costs of plants built within the last few years were given at the Symposium on Organisation of Chemical Engineering Projects organised in mid-summer by the parent body, the Institution itself. At this, data were presented for costs of five plants built between 1947 and 1957 broken down into the main cost components.

Apart from these formally published data, a few firms send out cost lists of items of equipment. We know that these firms often reap the benefit of their enterprise. When choosing between alternative suppliers for an item, if other things are equal, the engineer is likely to choose the one giving prices simply because that item will represent an accurate part of his estimate. Later it will physically go into his plant. For larger items unique figures may be difficult to give. Yet even here price bands on the relevant characteristic graph should be possible, defining the probable zone of cost even if sharp single lines are impracticable due to fluctuations in material costs or the load on the fabricating shop.

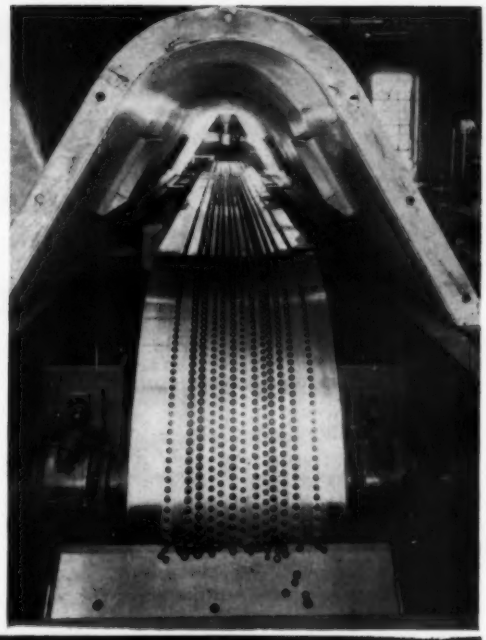
DR. WOOLCOCK has urged that cost estimates should be accompanied by estimates of their accuracy. Since this involves questions of market research which may govern scale of production, it is possibly a rather optimistic aspiration. How tightly can an individual firm plan in a generally unplanned *milieu*? There are obviously limits, but can these be estimated? Accuracy is also affected by the need to allow for units or additional stages possibly overlooked particularly in a new or unfamiliar process. Not all the difficulties are found at the development or pilot-plant stage and those found have not always been completely overcome before the pressure from elsewhere demands that the plant project must go ahead. To meet this it is wise to allow a contingency for ignorance or even for the optimism of researchers. As familiarity with a process and its problem grows the estimates can be made more precise and the allowances reduced. Several contributors urged a greater use of statisticians in examining data, particularly those based on market research and allied commercial topics. These are too often assessed by alleged wise men wrinkling their noses and foreheads over pages of tentative figures.

The provisional Programme for the forthcoming symposium on instrumentation and computation is due to include a paper on applying analogue computing to cost estimation for processes, plant and central systems. This implies a considerable order of accuracy for the data to justify data-handling by such techniques.

With the new information now available *for British conditions* and with the aid of mathematical statisticians to examine figures and set confidence limits, are we now approaching a time of more accurate cost estimation? We understand that when first approaches were made to firms by the organising committee the idea of this venture was warmly welcomed. Perhaps there is some change of heart. Is there now a growing realisation that it will be of benefit to all sides of the industry—plant suppliers, contractors, chemical producers—if we can move forward from "guestimation" to the beginnings of precise estimation?

66.046.5: 621.785.76

View from discharge end of pilot-plant Pastillator.



If pellets can be made in one stage from a melt, this eliminates an operation and avoids the formation of dust. In this article a successful process* of this type is described

THE PASTILLATION PROCESS

by S. N. ROSIN, M.A., and D. WORMALD

THE process and equipment described below were developed by the B.A.S.F. in Ludwigshafen in conjunction with the Maschinenfabrik Kaiser, of Krefeld-Uerdingen, and the Dr. Rosin Industrial Research Co. Ltd., of London, in order to solidify molten chemicals in one process, under closely controllable conditions, into discrete particles without the formation of powder and dust.

During the last decade or so, various machines have been developed to solidify molten products into pellets. In nearly all of them the principle has been the same, that is, dripping the molten product through a number of orifices on to a cooled surface. The cooled surface was a flaking roll, a turntable or an endless belt. Modifications using the shot-tower principle were also widely used. Apart from a few exceptions, when dripping a molten product from a static nozzle under the influence of gravity on to a cooled surface, relatively small pastilles are obtained, thus giving a low output per nozzle. Furthermore, these are rather flat, tend to stick to the cooling surface, break up and give a rather flake-like product. Another disadvantage is that the nozzles may block, often necessitating a higher operating temperature, and there is no adequate means of regulating the output, pastille size or the drop formation. Moreover, the flow of a viscous liquid from a static nozzle would not split into drops so that these could be cooled on a band.

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* *Fully patented.*

Symbols Used

Q_o = flow of liquid in cc/sec;
η = viscosity of liquid in poise;
ρ = density of liquid in g/cc;
g = acceleration due to gravity in cm/sec^2;
H = hydrostatic head, cm;
L = nozzle length, cm;
D = internal diameter of nozzle, cm;
d = diameter of plunger, cm; and
G = mean annular gap between plunger and nozzle bore, mm.

It was to overcome the above drawbacks that the mechanical pastillation process was developed. The molten product is fed through a feed valve to the Pastillator tank which is positioned above the cooling surface. This tank is fitted at the base with circular nozzles, through the centres of which a plunger reciprocates up and down, thus giving an annular nozzle of which the plunger constitutes the inner core. This action interrupts the steady flow of molten product and splits it up into separate drops. In effect, the intrinsic drop-forming tendency is being initiated and controlled by superimposing a cyclic mechanical force on the relatively weak surface forces due to the surface tension of the liquid. With non-viscous melts these drops, positioned at the end of the plungers, are deposited on to the cooling surface in such a manner that the drops retain their shape without flattening excessively. With viscous melts the advantages are even greater, as regular drop formation is obtained from rates of flow which otherwise would only split up in a shot-tower type of process, if at all. An advantage of the annular nozzle is that the cross-sectional area is greater than for a circular

nozzle of the same length and giving the same flow, so that the liquid comes out with a lower linear velocity and yet in a thinner film. The flow of liquid from such an annulus breaks up more readily into separate drops.

Nozzle System

The Pastillator tank only needs to hold a small quantity of material so that the residence time of the molten product is short. This enables one, if necessary when pastillating very viscous and thermal sensitive melts, to keep this vessel at a higher temperature than the header or production vessel, in order to pastillate the product at a lower viscosity. The Pastillator tank may be heated by any preferred method, either jacketed for hot water or steam heating, or equipped with electric heaters cast into an aluminium shell. The inside of the vessel, depending on the product, is usually made of stainless steel.

The plunger reciprocates up and down driven by a variable-speed drive and the rate of reciprocation is in the range of 150 to 400 strokes per minute according to the properties of the liquid or the output and size of pastilles required. For this process there are broadly two classes of liquid—mobile or "fluid" liquids which are liable to flatten on the cooling surface if allowed to drop freely, and viscous liquids for which the time taken by a jet to neck and split into drops tends to be excessive in the absence of mechanical reciprocation.

The reciprocation of the plunger has three functions which may be summarised as follows:

(a) To induce drop formation by intermittently retarding the flow of liquid from the nozzle. Once drop formation has been initiated, it is then completed by the surface tension forces of the liquid. This is especially important with viscous liquids.

(b) To deposit drops of non-viscous melts with the minimum of distortion. This is of importance, as we are dealing with drops of a larger size than formed under natural dripping, and if these were to drop any distance under their own weight they would splash or flatten out on contacting the cooling surface. When pastillating viscous liquids, drop deposition is not always possible as many of these products require longer necking times. On the other hand, drop deposition is not necessary as, owing to the greater viscosity, the drops do not flatten out to such an extent when hitting the cooling surface.

(c) To keep the nozzles free from clogging. The level of the melt is kept above the top of the nozzles so that any skinning which may occur does not block the nozzle. Furthermore the motion of the plunger is effective in clearing the nozzle of any obstructions such as fibre impurities or crystals.

The various stages in drop formation as the plunger moves up and down are illustrated in Fig. 3 when pastillating a fluid melt. The drop-forming process takes place as follows:

(i) At the top of its stroke the plunger is momentarily stationary and the liquid flows out of the annulus to form round the plunger as shown.

(ii) As the plunger descends an annular film of liquid flows down with it. The downward velocity of the plunger reaches a maximum at half its full stroke, and it then slows down as shown in the graph in Fig. 3. The velocity is seen to vary sinusoidally, since the plunger is driven by a circular eccentric motion of constant rpm. The annular film of liquid tends to overtake the plunger on the downward stroke—there is a balance at this stage between the downward pull on the liquid due to gravity plus the slight downward force due to the motion of the plunger and the viscous drag between the plunger and the thin liquid film. The result is that the liquid does not move as rapidly as if it had been falling freely from the nozzle height, as can be seen from Fig. 4.

(iii) As the plunger slows down towards the end of its downward stroke, the annular film of liquid which has by now become bulbous at the bottom of the plunger then forms a drop, the base of which makes contact with the cooling surface. With fluid melts the plungers are set so that the tip comes down to a height above the cooling surface which is a little less than the drop diameter. The plunger is again momentarily stationary at the bottom of its stroke and, as it slowly rises and the deposited drop is carried away by the moving band, the ensuing horizontal shearing action completes the detachment of the drop from the plunger. With very fluid melts, and those which tend to spread on the band, this depositing action is of importance, since it produces more nearly spherical pastilles than can be produced otherwise.

There is an optimum value for the minimum height to which the plunger tip comes above the cooling surface at the bottom of its stroke. Larger diameter flattened drops will result if this height is excessive, whereas distorted elongated drops are formed if the height is too low as the motion of the band drags out the liquid drop

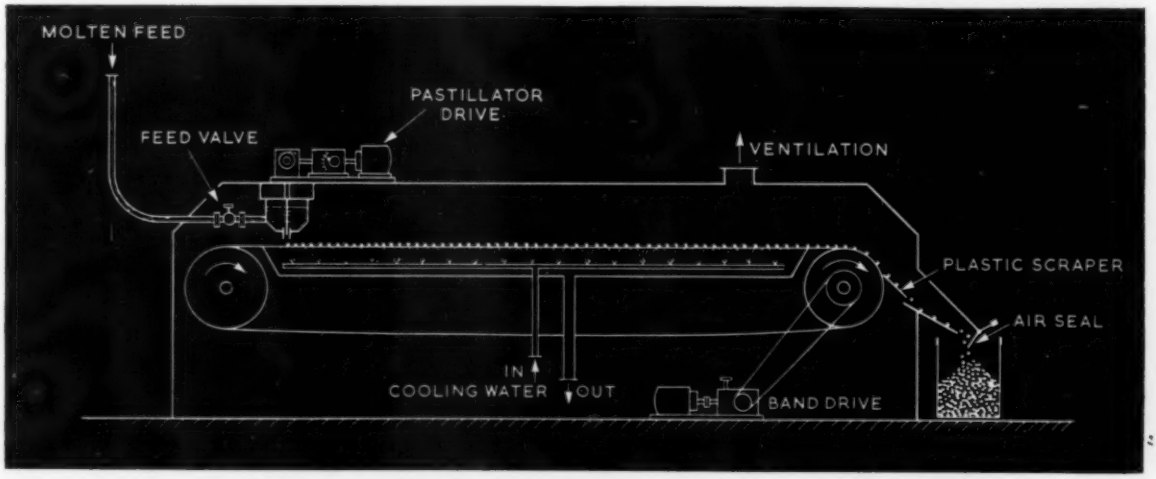

Fig. 1. Schematic diagram of totally enclosed Kaiser Rosin Pastillator.

whilst it is still attached to the plunger. However, there is a range within which satisfactory pastilles can be produced so that the functioning of the machine is not critical.

(iv) As the plunger rises, its velocity increases to a maximum half-way towards the top of the stroke. This upward velocity is of the same order as the downward velocity with which the liquid would be flowing through the annulus with a stationary plunger. This gives intermittent interruption of the flow and has the effect of braking the downward flow of the liquid coming out of the nozzle annulus. The liquid film already surrounding the plunger begins to accumulate towards the plunger tip as shown. As the plunger rises further and its velocity diminishes, more liquid flows out from the nozzle annulus to "fill" the drop which is forming round the plunger. After reaching the top of its stroke the cycle then continues as described in (i).

With viscous liquids the upward motion of the plunger is an important factor in interrupting the liquid flow to initiate drop formation, and larger strokes are sometimes used with such liquids in order to get higher plunger velocities and more of a disrupting action. Furthermore, the height above the band is often increased to give the drop formation more time for completion. Fig 5 shows a viscous product being pastillated under these conditions. The thread of liquid between the drop and the plunger breaks on the upward stroke and part contracts into the drop and part to the plunger. With viscous liquids much of the drop formation takes place beyond the plunger tip, whereas with fluid liquids the drop formation takes place around the plunger. With viscous liquids in particular, an optimum rate of reciprocation is observed which appears to synchronise with the rate at which the liquid is tending to neck. However, both with viscous and with fluid melts, it is possible to vary the rate of reciprocation over quite a wide range around the optimum value so that different pastille sizes may be produced for a given output; alternatively, by increasing both the rate of flow and the rate of reciprocation, different outputs may be produced with the same pastille size.

Flow and Nozzle Design

Each nozzle has an accurately produced circular bore inside which a round plunger is located so that the liquid flows through the annulus between the plunger and the bore. The bores of the nozzles for different products range from approximately 3 to 7 mm, while the plunger diameter is from 0.2 to 3 mm smaller, depending on the viscosity of the molten chemical and the size of pastille required.

The flow of the liquid through these annular nozzles is related to the liquid properties and the nozzle dimensions as follows.

Flow Relationships

The following equation is often given for the flow of liquid through a concentric annulus:

$$Q_o = \frac{\pi H \rho g}{128 L \eta}(D^2 - d^2)\left[D^2 + d^2 - \frac{D^2 - d^2}{\log \frac{D}{d}}\right] \quad \ldots . (1)$$

However, the use of this equation is not very practical when the values of D and d are close together, as is the case with many of the nozzle and plunger sizes we are concerned with.

The flow through the annular nozzles is best calculated from the formula for flow between parallel plates of breadth b, distance apart G and of length L.

$$Q_o = \frac{H \rho g}{12 L \eta} G^3 b \quad \ldots . (2)$$

For the annular nozzle the effective value of b will be taken as the mean perimeter, i.e.:

$$b = \pi \frac{D + d}{2} \quad \ldots . (3)$$

$$G = \frac{D - d}{2} \quad \ldots . (4)$$

$$\text{hence } Q_o = \frac{\pi H \rho g}{12 L \eta} G^3 \frac{D + d}{2} \quad \ldots . (5)$$

or using the kinematic viscosity $\nu = \frac{\eta}{\rho}$

$$Q_o = \frac{\pi H g}{12 L \nu} G^3 \frac{D + d}{2} \quad \ldots . (6)$$

In practice the plunger may not be absolutely concentric and can also be slightly skew relative to the nozzle axis. The increase in flow on the side of the plunger where the gap is increased then more than makes up for the reduction on the opposite side where the gap is reduced. The flow is therefore usually greater than the value given in Equation (6) for the ideal case where the plunger is perfectly concentric. It is also clear that the diameters of nozzles and plungers have to be very accurate, since the

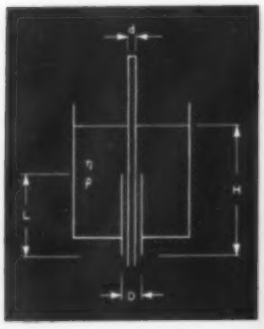

Fig. 2. Diagram of nozzle and plunger unit.

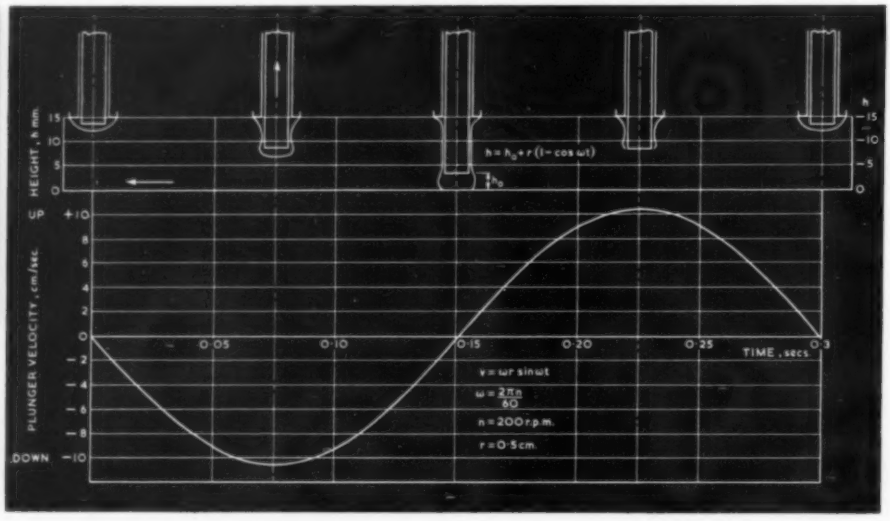

Fig. 3. Drop formation in relation to plunger movement.

flow is proportional to the cube of the annular gap. For example, with one product a change of plunger diameter of 0.1 mm gives the following differences in output.

Nozzle Bore *D*	*Plunger Diameter* *d*	*Output*
mm	mm	cc/min.
5.36	4.8	23.5
5.36	4.9	12.7

Thus, a high degree of precision is called for in manufacture and the nozzles are very accurately machined and the bore is finally reamered. The plungers are ground to close limits and polished. The dimensions are accurately gauged (pneumatically) to ensure that all nozzles will give a uniform output.

Cooling and Solidification

The pastille shape depends partly on the viscosity and spreading properties of the molten chemical and the highly polished surface of the stainless-steel band normally used gives a fairly high-contact angle for most melts, but, apart from this factor, the intrinsic spreading properties cannot be much influenced. However, by arranging efficient cooling on the underside of the thin band in the region where the drops are deposited, a rapid cooling of the drop as soon as it contacts the band ensures that the pastilles set before they have time to spread. To this end the temperature of fluid melts is also kept as close to the solidification point as possible.

Cooling Surface

The usual and preferred method is to cool the pastilles on an endless metal band carried between terminal pulleys at each end of the machine. An important feature of the process is that the drops are deposited and solidified upon a flat surface. When this surface is flexed to take the curvature of the terminal pulley the shearing action between the solid pastille and the band surface has the effect of causing the pastille to detach readily. Only a light plastic scraper fitted against the band where it runs over the terminal pulley is necessary and with many products the pastilles fall away from the band before even reaching the scraper. This is a considerable advantage over solidification on drum flakers which are usually constructed with a relatively thick shell so that cooling takes much longer. Here the products often adhere strongly to the metal surface, necessitating the use of heavy metal doctor blades pressed against the drum with some force, with the attendant disadvantage of high power consumption and the possibility of metal from the drum or scraper contaminating the product. Moreover, excessively large-diameter drums would have to be used if the drop is to solidify sufficiently so that it will not distort or run on the incline.

The Pastillator bands are commonly of stainless steel in which molybdenum can be incorporated when the product necessitates this. Nickel bands can also be used, for example with caustic alkalis. Bands are quite thin, usually in the range of 0.6 to 1 mm thick, thus giving a most efficient heat transfer. The band is water-cooled by a system of V jet nozzles used in a spray tank on the underside of the band, as can be seen in Fig. 1 which illustrates the overall functioning of a Pastillator. This system is preferred to the water-bed cooling system, as one obtains greater disruption of the water film on the underside of the band. The band speed is variable within the required working range and adjusted in relation to the rate of reciprocation so as to make the maximum linear use of the band space and available cooling path. The necessary length of the cooling zone is related to the band speed and to the required cooling time for the

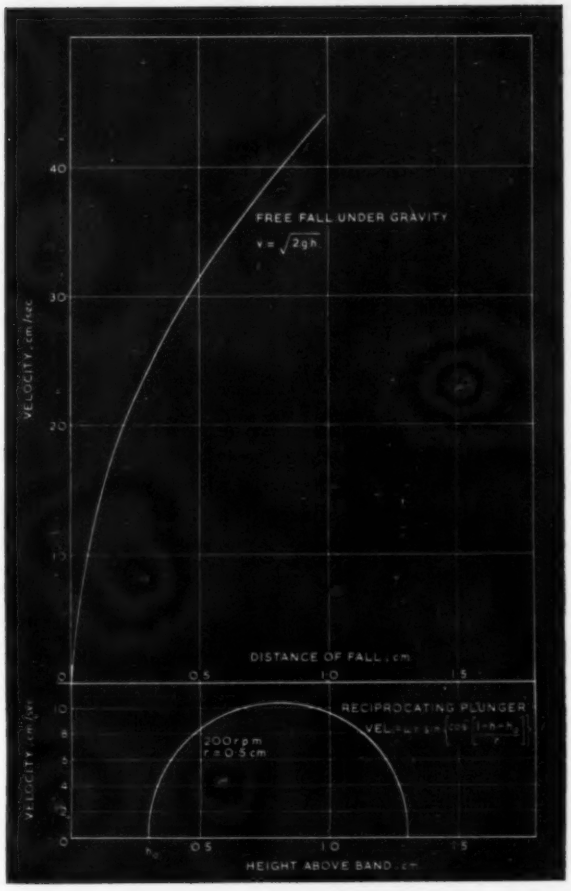

Fig. 4. Comparative velocity relationship between free falling drops and mechanical drop deposition.

largest output of the Pastillator and is dimensioned accordingly. The overall dimensions of these machines vary according to the product pastillated and the required capacities. The required capacity determines the width of the machine. The overall length, which may vary from 15 to 30 ft, depends mainly on the setting or cooling time required, and to a lesser extent on the rate of pastillation.

It is essential to dimension the nozzles, plungers, length of stroke and dripping or deposition heights specifically for each individual product. It is because of these vari-

Typical Conditions and Nozzle Dimensions for Three Different Types of Product

	Low Viscosity Melt *Maleic Anhydride*	Medium Viscosity Melt *Sodium Polymetaphosphate*	High Viscosity Melt *Ketone Amine Condensate*
Melting point (°C)	53	600–700	70–90
Operating temperature (°C)	55	740	120
Output per nozzle (lb./hr.)	4·5	21	9·5
Specific gravity	1·3	2·4	1·14
Nozzle dia. (mm.)	5·3	6·5	6·3
Plunger dia. (mm)	4·8	3·0	2·8
Rate of reciprocation per min	220	240	160
Band speed (ft/min)	8·0	9·0	6·0

Fig. 5. Pastillation of viscous product on pilot plant, showing nozzle and plunger mechanisms

Fig. 6. Two totally-enclosed twin unit Pastillators for maleic anhydride. (Photos: Monsanto Chemicals Ltd.)

ables that it is invaluable before designing and dimensioning production machines to carry out individual tests on a pilot unit designed for this purpose.

The output per nozzle for different products is also influenced by the specific gravity of the product. As the maximum width of the stainless-steel band obtainable in this country is 800 mm wide, a maximum of 76 nozzles may be used per single band unit.

Conclusions

Although melts can, in general, be pastillated with viscosities ranging from a centipoise to several hundred poise, there are a few molten chemicals with non-Newtonian flow properties which will not split up into drops but tend to string together in beads. This has been found with some high polymers.

Although substances with relatively low melting points, i.e., 40°C, may readily be pastillated, this is not always a practical proposition due to the fact that at high ambient temperatures the pastilles may tend to coalesce in containers. At the other end of the temperature scale products with melting points up to 750°C are being pastillated. The process has been applied with success to melts which supercool. By careful control of the cooling conditions continuous solidification into pastilles was achieved with substances which had otherwise to be solidified over a lengthy period in containers or trays.

One of the products for which pastillation has been found a great advantage is maleic anhydride. This used to be solidified on a drum flaker and then, owing to the toxic nature of the dust and powder formed, it had to be compressed into cubes. Due to the many disadvantages of this procedure, the pastillation process is now widely used for this product (see Fig. 6).

The ability to control drop formation and deposition within accurate limits has enabled us to develop a small experimental unit with three consecutive drop deposition mechanisms, so synchronised and positioned that large pastilles can be obtained by depositing three consecutive drops one on top of the other. As the drop from the first row of nozzles solidifies on the band, a second one is deposited on top of it. When the crystallisation of the latter has got under way a third drop is deposited on top and in this way one obtains very large pastilles composed of three separate drops but crystallised into one.

The practical advantages of the pastillation process may be summarised as follows:

(1) Formation of large regular drops under completely controllable conditions from high rates of flow or from liquids of high viscosities which was previously not possible.

(2) Whether fluid or viscous melts are pastillated, round, compact, free-flowing, regularly-shaped and dust-free pastilles are obtained in one machine at the expense of very little power, maintenance or supervision.

(3) The process is simple to operate and can be used with great advantage with poisonous, toxic, hygroscopic, temperature or oxygen sensitive materials.

Rotating Cylinder Fractionators

A Summary of a Paper on the Performance of the above columns is given below

AT A RECENT MEETING of the Institution of Chemical Engineers (North-Western Branch) held at Manchester, a paper on the "Studies on the Performance of Rotary Concentric Cylinder Fractionating Columns" was presented by DR. N. MACLEOD and MR. K. J. MATTERSON.

The fractionating column, which was essentially a wetted wall column, consisted of two concentric cylinders, the inner one rotated and the outer one stationary. Vapour from a still was passed through the annular space, was condensed at the top of the column and the liquid was returned to the column as a falling film down the stationary cylinder which was lagged and heated to prevent loss of heat from the column. Such a column had a low H.E.T.P., a low pressure drop and a low hold-up. The rotor operated in the vapour phase and mass transfer occurred across a stable, well-defined, vapour liquid interface of the liquid reflux that fell down the stationary wall. Previous workers had found an abrupt increase in separating power beyond a certain critical speed of the rotor; this increase was attributed to the onset of turbu'ence in the vapour phase. DR. MACLEOD reported a further advance in the theory of operation of wetted wall columns, the effect of TAYLOR vortices which are produced by the rotating cylinder at speeds below those that produce general turbulence, and efficiencies of the column in the region of turbulences and vortices.

With a *n*-heptane-methylcyclohexane mixture the main resistance to mass transfer was in the vapour phase. Although increases in rotor speed improved efficiency, in the lower column, once TAYLOR vortices were formed, the expected performance was not obtained. This was ascribed to back-mixing. Further increases in rotor speed did not influence efficiency until the region of turbulent flow was reached, when vortices were set up in the vapour phase.

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ASSOCIATED ETHYL'S NEW CHLORINE PLANT

Brine electrolysis by BASF process with mercury recirculation

THE chlorine plant installed by the Associated Ethyl Co. at Ellesmere Port represents approximately 5% of the installed manufacturing capacity for the material in the U.K. Despite the highly corrosive chemicals involved in the process, the plant has operated continuously for several months with very little trouble due to mechanical defects or corrosion; the health and safety record is excellent.

Electrolysis of brine solution is carried out in mercury cells as designed and operated by Badische Anilin & Soda Fabrik A.G. Brine purification, dechlorination and re-saturation is also carried out according to BASF processes. The chlorine produced is dried by vitriol circulation through towers, compressed using Nash compressors and liquefied by two-stage refrigeration from a CO_2 system. In order to utilise dilute chlorine gas, which has passed unliquefied through the liquefaction system, and also vent gases resulting from air pressure transfers of liquid chlorine, it was decided to install a chlorine-recovery process. The process developed by The Diamond Alkali Co. of the U.S.A. was chosen as most suitable.

Pure concentrated brine is fed to the cells. It leaves the cells at a lower concentration and is then slightly acid due to dissolved chlorine. The chlorine is removed from the brine by acidification, vacuum and air blowing. Remaining traces of chlorine are removed by treatment with sodium sulphide solution. One-third of the dechlorinated brine stream is fed into one of the salt storage pits and serves to carry a slurry of salt into the brine preparation tanks, where the slurry is agitated with the remainder of the brine to re-saturate the solution. NaOH, Na_2CO_3 and $BaCO_3$ are also added to remove magnesium, calcium and sulphate. The resulting precipitates are removed by filtration through two Kelly pressure filters in series.

All brine equipment is constructed of materials that are anti-corrosive and will not give risks of contamination of the brine with traces of elements (V, Cr, Mo) which are known to cause decomposition of sodium amalgam. Much of the equipment is rubber-lined.

Cellroom equipment

The BASF mercury cell consists of a rubber-lined trough containing a layer of mercury which forms the cathode. The graphite anodes, which are horizontal plates, are suspended from the cell cover by vertical graphite stubs which protrude through the cover. Electrical connection to the mercury is made by means of iron "mushrooms" set in the rubber lining of the cell trough and connected through the bottom of the cell. On application of current to a brine-filled cell, chlorine is discharged at the anode and an amalgam of sodium forms at the mercury cathode. The brine cell is sloped so that the mercury amalgam continuously travels along the length of the cell; the amalgam then passes a separating weir and enters a "decomposer", where it reacts with water to form caustic soda and hydrogen. The mercury is then recirculated from the "decomposer" discharge by pump to the brine cell.

One of the features of mercury cells, as contrasted with the alternative of diaphragm-type cells, is that they provide the highest grade of commercial caustic liquor without further process treatment. In this instance, 100°Tw. caustic liquor (46.7% NaOH) will be produced.

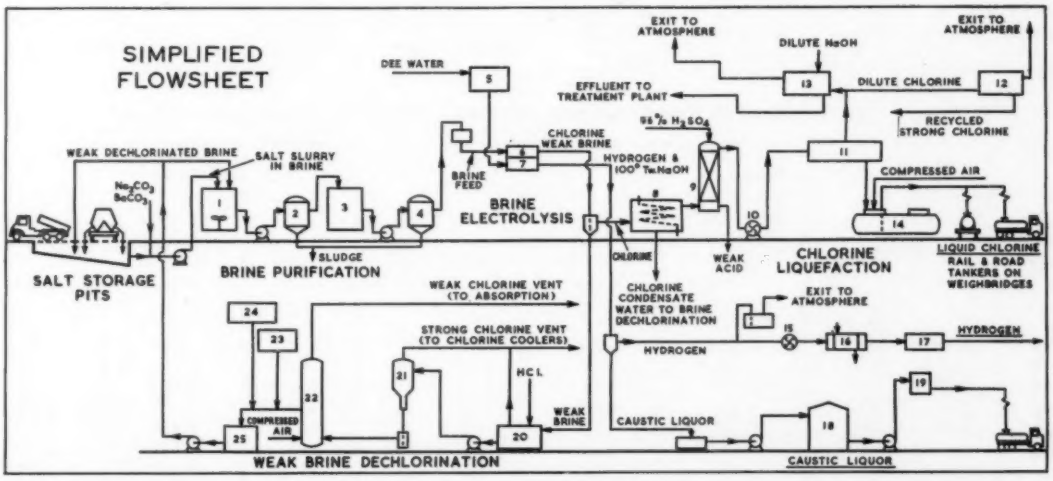

Fig. 1.—1, *brine treatment;* 2, *raw brine filters;* 3, *purified brine;* 4, *purified brine filters;* 5, *water treatment plant;* 6, *brine cells;* 7, *amalgam decomposers;* 8, *chlorine coolers;* 9, *chlorine drying towers;* 10, *Nash compressors;* 11, *chlorine liquefiers* (CO_2 *refrigeration);* 12, *chlorine recovery plant;* 13, *chlorine absorption plant;* 14, *liquid chlorine storage;* 15, *blower;* 16, *cooler;* 17, *Purifier;* 18, 100° *Tw. NaOH storage;* 19, *Measuring tanks;* 20, *Acidifiers;* 21, *vacuum towers;* 22, *air blowing towers;* 23, Na_2S; 24, *NaOH; and* 25, *weak brine tanks.*

66.061.5

ANALYSIS OF BATCH-OPERATED EXTRACTION PROCESSES—PART II

In this part of his article,* the author gives two examples analysing the performance of batch extraction processes

by G. V. JEFFREYS

Example I

100 gal. (1000 lb.) of a feed liquor containing 25% by weight of oleic acid in cotton seed oil is to be extracted in a batch-operated extraction plant containing five theoretical trays. If the plant is to be operated with a constant reflux ratio of 4.0 calculate the weight of product of 85% purity obtained, using propane as solvent.

The equilibrium data were plotted on a solvent-free basis on rectangular co-ordinates as shown in Fig. 9. For the system under consideration a solutrope is formed at just over 93% oleic acid (solvent-free basis) and therefore an initial extract composition of 93% acid was chosen.

Thus, at extract composition 0.93 oleic acid

$N_{E_1} = 12.0$ lb. solvent/lb. hydrocarbon

and, for a reflux ratio of 4.0. $4.0 = \dfrac{N_Q - N_{E_1}}{N_E} = \dfrac{N_Q - 14.5}{14.5}$

$\therefore N_{Q_1} = 72.5$ lb. solvent/lb. hydrocarbon

With this value of N_{Q_1} and an extract composition of 0.93 acid, five stages were stepped off to give the composition of the acid in the mixer as $x_w = 0.24$, as shown in Fig. 9.

* *Part I was published in the November issue, page 594.*

In a similar manner the composition of the liquid in the mixer was evaluated for extract compositions of 0.9; 0.85; 0.80; 0.75, and 0.70. The graphical construction is shown on Fig. 9 and the results are summarised in Table 2.

From these results X_{CE} was plotted versus X_{CR} and the results are shown in Fig. 10.

With the aid of Fig. 10 the equation

$$\text{Log}_e \frac{F}{R} = \int_{X_R}^{X_f} \frac{dx}{X_E - X_R}$$

can be integrated graphically. Thus X_{CR} is plotted against $\dfrac{1}{X_{CE} - X_{CR}}$ on Fig. 11 and the area between $X_F = 0.25$ and the different values of X_{CR}, under the integration curve determined. From the particular value of the integral the quantity of product and its bulk composition determined. The results are summarised in Table 3.

The calculations yielding the weight of product and its composition are made as follows. Consider the point where the extract product composition is $X_E = 0.93$.

Value of integral $= 0.0144 = \text{Log}_e \dfrac{F}{R} = 2.303 \text{ Log}_{10} \dfrac{1000}{R}$

Table 1. Liquid-liquid equilibrium data system, propane — oleic acid — refined cottonseed oil.[7]

Extract (Upper Phase)					*Raffinate (Lower Phase)*				
Cotton Seed %	*Oleic Acid %*	*Propane %*	*lb. Acid / lb. Hydrocarbon*	*lb. Propane / lb. Hydrocarbon*	*Cotton Seed %*	*Oleic Acid %*	*Propane %*	*lb. Acid / lb. Hydrocarbon*	*lb. Propane / lb. Hydrocarbon*
2.3	0.0	97.7	0.0	42.5	63.5	0.0	36.5	0.0	0.575
1.95	0.76	97.3	0.281	36.0	57.2	5.5	37.3	0.088	0.595
1.78	1.21	97.0	0.405	32.4	52.0	9.0	39.0	0.148	0.64
1.50	1.90	96.6	0.559	28.4	46.7	18.8	39.5	0.228	0.652
1.36	2.73	95.9	0.666	23.4	39.8	18.7	41.5	0.320	0.709
1.20	3.80	95.0	0.760	19.0	31.0	26.3	42.7	0.454	0.745
1.10	4.4	94.5	0.800	17.2	26.9	29.4	43.7	0.522	0.775
1.0	5.1	93.9	0.835	15.4	21.0	32.4	46.6	0.605	0.873
0.8	6.1	93.1	0.885	13.5	14.2	37.4	48.4	0.725	0.938
0.7	7.2	92.1	0.912	11.68	8.3	39.5	52.2	0.826	1.093
0.4	6.1	93.5	0.938	14.4	4.5	41.1	54.4	0.902	1.193
0.2	5.5	94.3	0.965	16.5	0.8	43.7	55.5	0.982	1.248

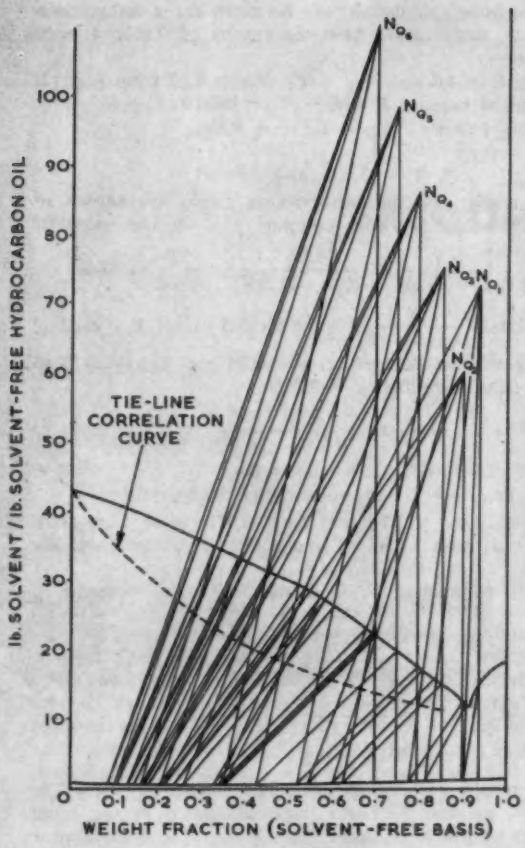

Fig. 9. Five-stage process at constant reflux ratio.

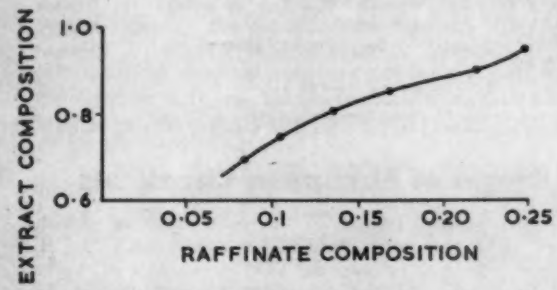

Fig. 10. Relation between instantaneous extract and raffinate compositions.

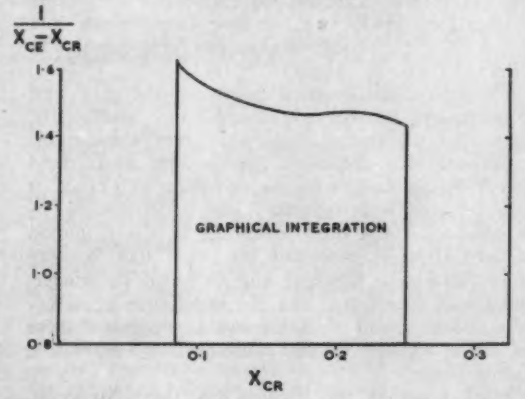

Fig. 11. Equation (6) between limits set in Example 1.

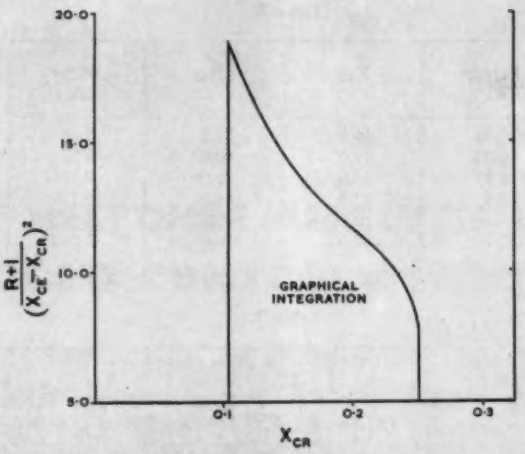

Fig. 13. Graphical integration of Equation (21) between limits set in Example 2.

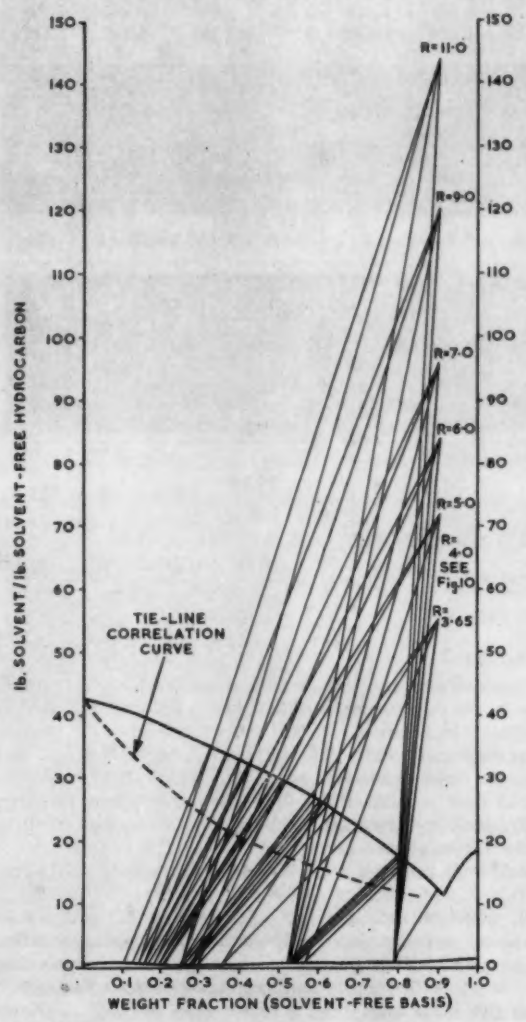

Fig. 12. Stepwise graphical construction of five-stage batch extraction process operating with variable reflux ratio.

Table 2.

Extract X_{CE}	N_{E_1}	N_Q	*Mixer* X_{CR}
0.93	14.5	72.5	0.24
0.90	12.0	60.0	0.22
0.85	15.0	75.0	0.168
0.8	17.3	86.5	0.136
0.75	19.6	98.0	0.103
0.70	22.0	110.0	0.084

Table 3.

X_E	X_{CR}	$\frac{1}{X_E - X_R}$	$\frac{dX}{X_E - X_R}$	*R. lb. Residue*	X_P *Product*	*lb. Product*
0.93	0.24	1.450	0.0144	985	0.935	15.0
0.90	0.22	1.470	0.0438	957	0.908	43.0
0.85	0.168	1.463	0.1180	888	0.900	112.0
0.80	0.136	1.506	0.1670	846	0.878	154.0
0.75	0.103	1.543	0.216	805	0.857	195.0
0.70	0.084	1.620	0.247	780	0.845	220.0

Table 4.

Reflux Ratio R 1	X_{CE} 2	X_{CR} 3	*lb. Extract* 4	*lb. Raffinate* 5	$\frac{(R+1)}{(X_{CE}-X_{CR})^2}$ 6	*Integral* 7	*lb.* G 8	*Hrs. Time* 9
3.65	0.9	0.25	—	1000	7.93	—	—	—
4.0	0.9	0.22	45	955	10.80	0.29	189	1.34
5.0	0.9	0.192	82	918	11.98	0.602	390	2.8
6.0	0.9	0.168	112	888	13.08	0.913	592	4.2
7.0	0.9	0.150	134	866	14.22	1.151	748	5.3
9.0	0.9	0.124	162	838	16.62	1.553	1008	7.2
11.0	0.9	0.104	174	826	18.94	1.983	1290	8.6

or $\text{Log}_{10}\frac{1000}{R} = 0.0063$ and $\frac{1000}{R} = 1.015$ or $R = 985$ lb.

and Weight of product $= 1000 - 985 = 15$ lb.

Composition of product $= \frac{(1000 \times 0.25) - (985 \times 0.24)}{15}$

$= 0.935$

Example 2

Suppose that the multi-stage batch extraction of example 1 is to be carried out in the same equipment, but that it is desirable to withdraw an extract product of constant composition, of 90% oleic acid. It will be further assumed that the unit possesses plates for which the maximum liquid flow is 60 ft³/ft² hr. It is desired to show how the reflux ratio will have to be changed as a function of time, if the sectional area of the column is 2.0 ft.²

Density of propane = 14.4 lb./ft³ and density of hydrocarbon = 53 lb./ft.³

Equilibrium data are replotted on Fig. 12, and a trial graphical stepwise construction shows that the initial reflux ratio = 3.65. That is, an extract product composition $X_{PE} = 0.9$ will yield a raffinate composition $X_{CR} = 0.25$ with five ideal stages and a reflux ratio of 3.65, as shown on Fig. 12. The raffinate compositions, corresponding to $X_{PE} = 0.9$ and with greater reflux ratios were obtained by the graphical procedure given in this paper. The results are summarised in Table 4, columns 1, 2, 3.

A specimen calculation will be given for a reflux ratio of 4.0 to demonstrate how the results of Table 4 were obtained:

When $R = 4.0$ and $X_{PE} = 0.9$, $X_{CR} = 0.22$ from Fig. 12.

By material balance $F = E + R$ or $1000 = E + R$.

By solute balance $FX_{CF} = EX_{PE} + RX_{CR}$

or $250 = 0.9E + 0.22R$.

$\therefore R = 955$ lb. and $E = 45$ lb.

The results for the other reflux ratios are shown in columns 4 and 5. From columns 1, 2, 3, the value of

$$\frac{R+1}{(X_{CE} - X_{CR})^2} = \frac{5.0}{(0.9 - 0.22)^2} = \frac{5.0}{0.462} = 10.8$$

The values of $\frac{R+1}{(X_{CE} - X_{CR})^2}$ are plotted versus X_{CR} on Fig. 13, and the area between $X_{CR} = 0.25$ and $X_{CR} = 0.22$ in terms of the co-ordinates = 0.29.

Then $G = F(X_{CE} - X_{CR})\frac{(R+1)\,dx}{(X_{PE} - X_{CR})^2}$

$= 1000\ (0.9 - 0.25)\ 0.29 = 188.8$ lb.

i.e., $G = 189$ lb. solvent-free hydrocarbon

From Fig. 12 it will be seen that 12.0 lb. solvent are associated with each 1.0 lb. of hydrocarbon leaving the tower top.

$\therefore$ Total volumetric flow off the top of the column

$$= \frac{12.0 \times 189}{14.4} + \frac{189}{53}$$

Maximum liquid flow is 120 ft³/hr.

$\therefore$ Period $= \frac{157 + 3.5}{120} = \frac{160.7}{120}$

$= 1.3$ hours

The results for the other reflux ratios are shown in Table 4, column 9. These were calculated in the same way. Inspection of columns 1 and 9 of Table 4 shows how the reflux ratio should be changed with time.

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Origin of European Chemicals

AT THE ANNUAL DINNER of the Association of British Chemical Manufacturers held in London recent'y Mr. B. Hickson, chairman, announced that, as a result of weeks of detailed work by the Association's committee on the European Free Trade Area, a scheme for the definition of the origin of chemicals by process criteria acceptable by the Board of Trade and Customs Departments had been drawn up, and it now formed the basis for negotiation in O.E.E.C. in Paris.

The Association had discused informally the plan with their counterparts in Western Europe, and, unofficially, they knew that the chemical manufacturers' associations of the Scandinavian countries, Austria and Switzerland approved it. In addition, with the exception of France, it had been received with sympathy and understanding by the associations in the other countries of the Common Market. Mr. Hickson expressed the belief that Western Europe contained the financial and technical knowledge, the capital and equipment, and the experience of democracy and culture ahead of all the world, and that if these were harnessed together Europe could become a stabilising and leading power.

The chief guest at the dinner was Lord Mancroft, Minister with Portfolio.

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FREQUENCY RESPONSE ANALYSIS IN PROCESS CONTROL—PART I

A tool for predicting the stability of an automatic process-control system and for making the optimum adjustments to it

by K. GOITEIN, A.M.I.E.E., A.M.I.Mech.E

THE rational planning and design of a controlled process plant depends on the possibility of predicting the dynamic behaviour of the plant under all conditions of operation, i.e., its response to all kinds of disturbances and to the corrective actions of regulators. Frequency response analysis has been well known in the field of servomechanisms for some considerable time; its use in process control, however, is comparatively recent, and some controversy still exists regarding its value and scope of useful application.

Briefly, frequency response analysis is the evaluation of the response of a system to damped or undamped sinusoidal inputs of different frequencies. The term "system" has, in this context, a very general meaning; it may be a complete process plant, a controller or any component of either; it may be an open or a closed-loop control system. It can perhaps be defined as an aggregate of two or more physically (mechanically, electrically or chemically) interacting units.

The choice of sinusoidal inputs for system response analysis may appear arbitrary, and, in fact, various other forms of analysis have been suggested. Actual disturbances in a control loop vary considerably. They may approximate to a "step function", that is, an abrupt change of a variable between two distinct values, or a "ramp function", which is a linear change. Exponential disturbances are also frequently encountered. The sinusoidal disturbance appears to be the exception rather than the rule. Nevertheless, there are a number of reasons justifying frequency-response analysis in preference to other forms of treatment. Primarily, it is a means of evaluating the conditions of inherent stability, that is, the conditions which determine whether or not an oscillation, once started by some form of disturbance, is sustained through regeneration within the loop after the disturbance has ceased. Here the form of the transient disturbance is irrelevant. Frequency response analysis is also a useful method of determining the optimum control adjustments and of promoting a better understanding of the working of control systems. It is capable of comparatively simple mathematical treatment and graphical presentation; in many cases, it can be applied experimentally to an existing plant, without undue interference with the process, or to an analogue in the design stages.

Mr. Goitein *studied mathematics, physics and electrical engineering in Vienna. Before the war he was the senior research engineer in the process control instrument division of Junkers Werke, Dessau; he joined Elliott Brothers (London) Ltd., as chief engineer of the Process Control Division in* 1948.

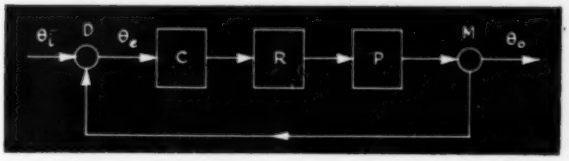


Fig. 1. Simplified block diagram of closed control loop.

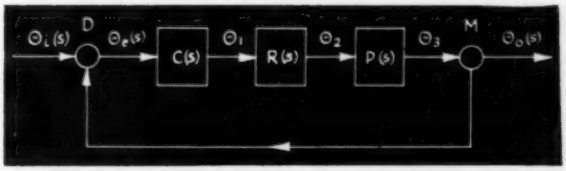


Fig. 2. Closed-loop block diagram of transfer functions.

In this article an elementary treatment of the fundamentals of frequency response analysis is given with particular reference to process control applications. The emphasis is not on theoretical completeness or exactitude, but an attempt is made to explain the principles with a minimum of mathematical complexities.

Fundamentals

In a simplified way, a closed control loop can be represented in the form of a block diagram (Fig. 1). The controlled variable, θ, e.g., a temperature, pressure, flow rate or liquid level, is held at or near the desired value, θ_i (the input), by the action of the regulator, R, which is controlled by the controller, C, on the plant, P. The output value of the variable, θ_o, is measured by the instrument, M, and fed back to the difference device, D, which produces the error signal or deviation, $\theta_e = \theta_i - \theta_o$, which operates the controller.

The Potential Value

It is to be noted that the action of the controller and that of the regulator make use of variables other than the controlled variable. In a pneumatic temperature con-

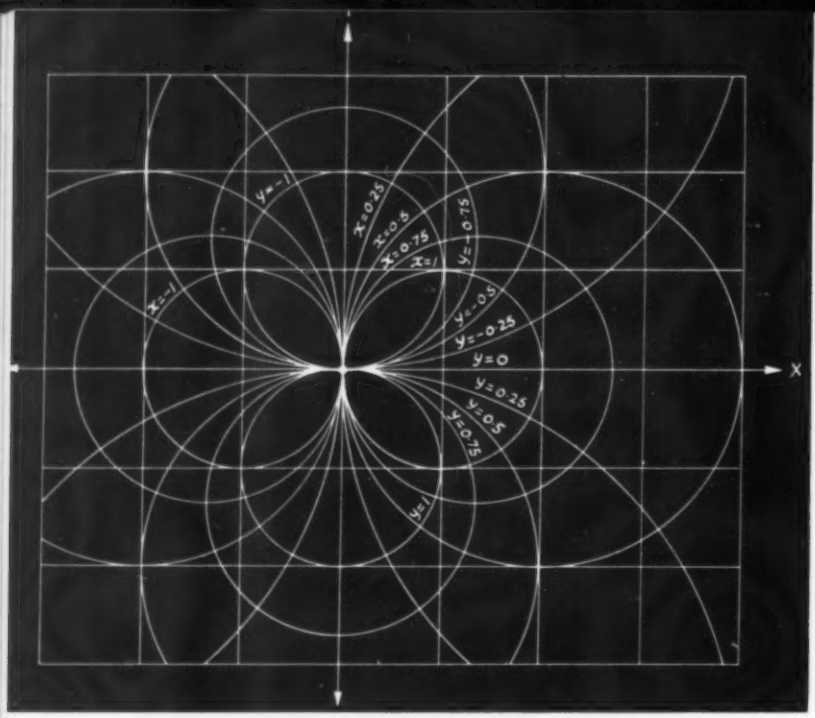
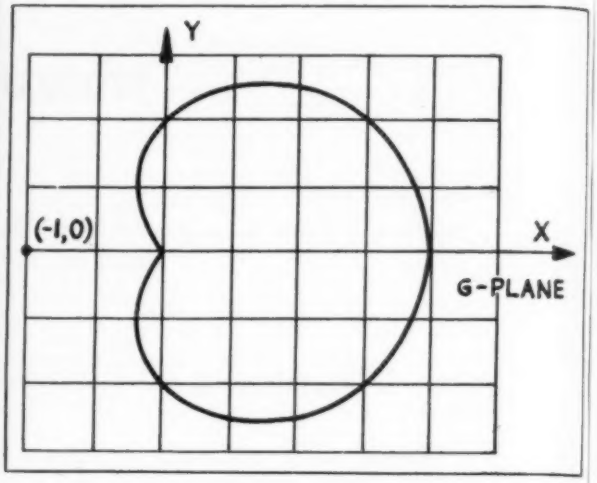


Fig. 3. Mapping of function $G(s) = \frac{1}{s}$.

Fig. 4. Transfer locus of $G(s) + \frac{1}{(s+0.5) \cdot (s+1)}$.



troller compressed air is used to operate a pneumatic valve which varies the flow rate of a heating or cooling medium which, in turn, affects the temperature, the controlled variable. The concept of the "potential value" has been introduced so that the whole control loop can be represented in terms of a single variable. In simple terms, the potential value of the controlled variable is the value which corresponds to a given value of another variable in the control loop, that is, the value it would assume in the absence of feed-back control. In the above example, a given air pressure applied to the control valve will, in the absence of other influences, produce a certain temperature value which is the potential value of the temperature corresponding to the given air pressure. By introducing this potential value of the controlled variable in place of any other variable used in the control loop, the treatment of control problems can be considerably simplified since one variable only is used throughout.

Linear Systems

For the purposes of simplified mathematical treatment, control systems are generally assumed to be linear systems. These are systems that can be described by linear differential equations with constant coefficients, or, in less abstract language, systems in which the effects are proportional to the causes. In practical systems this is by no means generally the case, but linearity is a reasonable approximation for small changes of variables. Non-linear systems can therefore be treated as linear systems for each particular value and for small changes of the variables.

Differential equations describing a system can be solved in various ways. The classical methods are often rather involved and cumbersome; the operational method in which the symbols of differentiation and integration are treated as algebraic factors reduces differential equations to algebraic equations; the Laplace transformation, which is of more general application, serves the same purpose. It also forms the basis of frequency response analysis.

Dynamic Response

The controlled variable, in an ideal control system, should deviate only very slightly from a constant value. In practice, however, disturbances will occur, such as sudden or gradual changes in supply or demand and certain random variations of plant conditions. When such a disturbance occurs the controlled variable may respond in various ways: it may return to its original value after a transient damped oscillation; it may approach a new value asymptotically; or it may start oscillating continuously with the natural frequency of the system with constant or increasing amplitude. In the latter case, the system is said to be unstable.

In a closed control loop, the response of the variable to a primary disturbance itself acts as a secondary disturbance. It is important to appreciate that primary disturbances of comparatively short duration are of minor importance, provided the loop is inherently stable. This occurs if its response does not set up a sustained oscillation in the control loop after the primary disturbance has ceased. Frequency response analysis, in dealing with system response to sustained oscillations, is a means for determining the conditions for regeneration of an oscillation within the loop, that is, for instability and, by exclusion, of course, also the conditions for inherent stability, and the controller types and settings required to achieve it.[10]

Frequency response analysis can be carried out in three different ways: mathematically, if all the system parameters are known or can be estimated; on an existing plant, by means of an artificial sinusoidal input and measurement of the response; and, finally, by means of an analogue device or simulator. The mathematical approach makes use of the Laplace transformation.[2, 6]

Laplace Transformation in Frequency Response Analysis

A mathematical treatment of the Laplace transformation is beyond the scope of this article; only its general principles will be explained, with particular reference to frequency-response analysis.

The Laplace transform makes use of the concept of "complex frequency" usually designated by the letter "*s*". This may be explained in the following way:

A function $f(t) = A \cdot e^{st}$ in which s is a complex number: $s = \alpha + j\omega$ can also be written in the form:

$$f(t) = A \cdot e^{\alpha t} \cdot e^{j\omega t}. \qquad \ldots . (1)$$

This function represents a damped oscillation if α is

negative, A being the initial amplitude, $-\alpha$ the damping factor and ω the angular frequency, i.e., $2\pi f$; f being the frequency in cycles per second. For $\alpha = 0$, Equation (1) is reduced to a sinusoidal oscillation; for $\omega = 0$ it represents an overdamped or asymptotic approach. If α becomes positive, the amplitude of the oscillation increases to infinity (or, in practice, to the limits of the system's capacity). It is thus seen that the exponential function

$$f(t) = A \cdot e^{st} \qquad \ldots.(1a)$$

—in which s is a complex number as defined above—is a general expression covering all the forms of system response according to the values and signs of the real and imaginary components of s.

The Laplace transformation converts a function of time into a function of this complex frequency s. The Laplace transform of a time function $f(t)$ is defined by:

$$\mathcal{L}[f(t)] = F(s) = \int_0^\infty f(t) \cdot e^{-st}\, dt \qquad \ldots.(2)$$

The Laplace transform has certain important properties stated here without proof.

(a) The Laplace transform of a sum of functions is the sum of the individual transforms; a constant factor is not affected by the transformation.

$$\mathcal{L}[a \cdot f_1(t) + b \cdot f_2(t)] = a \cdot F_1(s) + b \cdot F_2(s) \qquad \ldots.(3)$$

(b) The Laplace transforms of power, exponential and trigonometric functions are algebraic functions; e.g.:

$$\mathcal{L}[t^n] = \frac{n!}{s^{n+1}} \qquad \ldots.(4)$$

$$\mathcal{L}[e^{-at}] = \frac{1}{s+a} \qquad \ldots.(5)$$

$$\mathcal{L}[\sin \omega t] = \frac{\omega}{s^2+\omega^2} \qquad \ldots.(6)$$

$$\mathcal{L}[\cos \omega t] = \frac{s}{s^2+\omega^2} \qquad \ldots.(7)$$

(c) The transforms of differential coefficients and integrals have algebraic forms:

$$\mathcal{L}[f'(t)] = s \cdot F(s) + f(0+) \qquad \ldots.(8)$$

$$\mathcal{L}[\int f(t)dt] = \frac{F(s)}{s} - \frac{\int f(0+)}{s} \qquad \ldots.(9)$$

These properties of the Laplace transform provide the basis for transforming, term by term, any system equation containing time functions and their differential and integral terms into an algebraic equation which can be solved by algebraic methods. To find the solution in terms of a time function, the inverse Laplace transformation can be applied. Although an explicit form for the inverse Laplace transformation exists, it is seldom applied in practice; the usual method is the use of tables of Laplace transform pairs found in many textbooks. (Some of these transform pairs are shown in Equations (4) to (7).) If the solution is in the form of a more complex algebraic polynomial fraction, it is expanded by the usual methods into simple partial fractions, the inverse transforms of which can be read from the tables. For the purpose of studying the behaviour of a system, this re-transformation is, however, quite unnecessary; the characteristics of the system, particularly its response to damped or undamped sinusoids and its stability limitations, can often be derived from an inspection of the Laplace-transformed solution of the system equation.

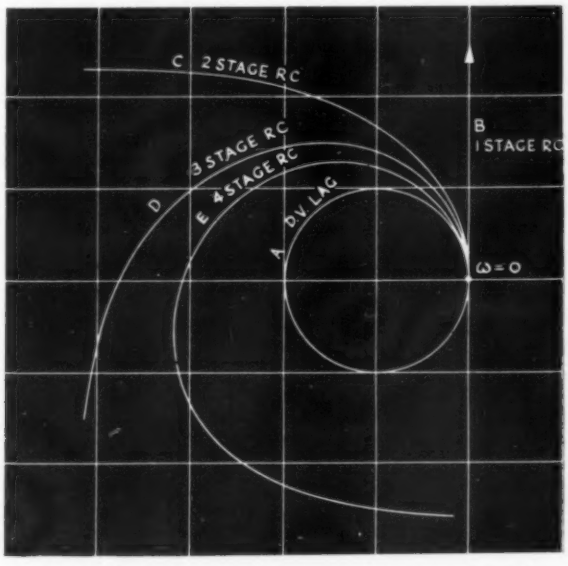


Fig. 5. Typical polar diagrams of single- and multi-stage RC plants and of DV lag.

The Transfer Function

Fig. 1 shows a simplified control loop in which a variable θ, which is a time function, is subjected to modifying actions as it passes through the various elements of the loop. The same loop can be represented in terms of Laplace transforms. In Fig. 2, the variable is Θ, which is the Laplace transform of θ, and, as such, a function of the frequency s. The blocks represent the functional relationships between the input and the output of the corresponding elements; e.g.:

$C(s) = \frac{\Theta_1}{\Theta_e}$, the ratio of output to input of the controller;

$R(s) = \frac{\Theta_2}{\Theta_1}$, the ratio of output to input of the regulator,

and so on. These ratios, which are functions of the generally complex variable s, are called transfer functions of the corresponding elements. The transfer function fully characterises the dynamic response of a system, i.e., its response to any damped or undamped sinusoidal input or an exponential input, and its stability conditions. It is in the nature of linear systems that their transfer functions are simply factors of multiplication and that consecutive transfer functions of a control loop can be multiplied. Thus, the complete transfer function of the open control loop of Fig. 2 is:

$$G(s) = \frac{\theta_o}{\theta_e} = C(s) \cdot R(s) \cdot P(s) \qquad \ldots.(10)$$

From the above description of the properties of the Laplace transform, it follows that the transfer functions which are Laplace transforms of ordinary linear differential and integral functions are of algebraic form. Their mathematical treatment is, therefore, much simpler than that of the original time functions. Therein lies their principal value.

In the general case, the transfer function of a linear system will have the form:

$$F(s) = \frac{A(s)}{B(s)} \qquad \ldots.(11)$$

where $A(s)$ and $B(s)$ are algebraic polynomials. If the roots of the equation $B(s) = 0$ can be evaluated, $F(s)$ can be represented as a sum of partial fractions which can usually be recognised individually as Laplace transforms of known time functions by reference to a table of Laplace

transforms. In particular, if one of the roots is a positive real number a, then one of the partial fractions will have the form $\frac{b}{s-a}$ which is recognisable from Equation (5) as the Laplace transform of $b \cdot e^{at}$. As this tends to infinity with time, the system will be unstable. Conversely, negative real roots indicate stable components of the system. Imaginary roots (see Equations (6) and (7)) indicate sinusoidal oscillation and complex roots damped oscillation, if the real part is negative, or increasing amplitude, if the real part is positive. Thus, the analysis of the transfer function of a system allows conclusions to be drawn regarding its inherent stability.

Stability Criteria

As shown above, instability occurs if the roots of the denominator of the transfer function have positive or zero real parts. Various stability criteria have been developed which can be applied to transfer functions without the necessity of partial fractionisation. ROUTH's criterion of stability, which will not be discussed in detail here, is a method of determining from the coefficients of an algebraic polynomial whether there are any roots with positive real parts.[2]

NYQUIST's criterion uses a graphical presentation of the transfer function. A simplified explanation of its principle is given below.[10] Referring to Fig. 2 and Equation (10), the transfer function of the closed loop can be derived from that of the open loop, $G(s)$, in the following way:

$$\frac{\theta_o}{\theta_i} = \frac{\theta_o}{\theta_o+\theta_e} = \frac{G(s)}{1+G(s)} \qquad \ldots (12)$$

$G(s)$ is a complex valued function of a complex variable. As such, it cannot be represented graphically in a plane or even isometrically in a three-dimensional way. The method of graphical presentation generally adopted is known as "mapping". This technique is briefly explained below.

The complex variable $x + jy = s$ is represented in the "s"-plane as a point with the co-ordinates x and y. Similarly, the complex function $G(s) = X(s) + Y(s)$ is represented in the "G"-plane as a point with co-ordinates X and Y. To each point in the "s"-plane there is a corresponding point in the "G"-plane, according to the relationship given by the function $G(s)$. Thus, any curve or straight line in the "s"-plane can be mapped on to the "G"-plane. In particular, a system of rectangular co-ordinates in the "s"-plane can be mapped on to the "G"-plane as a system of curvilinear co-ordinates.

To illustrate the mapping procedure by way of a simple example, the function $G(s) = \frac{1}{s} = \frac{1}{x+jy}$ can be written in the form: $G(s) = \frac{x-jy}{x^2+y^2} = \frac{x}{x^2+y^2} - j \cdot \frac{y}{x^2+y^2}$. The real axis in the "$s$"-plane, that is, the values of s for which $y = 0$, is represented on the "G"-plane by $G(x) = \frac{1}{x}$ while the imaginary axis, that is, $x = 0$, is mapped into $G(jy) = -j \cdot \frac{1}{y}$. In this particular case, the positive "x"-axis is mapped into the positive "X"-axis, but the "y"-axis is transformed into the negative "Y"-axis, the corresponding points on these axes having reciprocal co-ordinates. It can easily be shown that lines in the "s"-plane parallel to the "y"-axis are mapped into circles passing through the origin with centres on the "X"-axis and lines parallel to the "x"-axis into circles through the origin with centres on the negative "Y"-axis (see Fig. 3).

It has been shown above that a system will generally be unstable if the roots of the denominator of the transfer function have zero or positive real parts; or, in other words, if the denominator becomes zero for any value of s in the right half of the "s"-plane, including the imaginary axis. This principle, applied to the overall transfer function of the closed loop $\frac{G(s)}{1+G(s)}$ (Equation (12)), means that $1 + G(s)$ must not become zero, or $G(s)$ not -1, for any point s on the right half (including the "y"-axis) of the "s"-plane.

This, essentially, is NYQUIST's stability criterion which can be used to determine graphically if a single closed loop is stable. The procedure is as follows: A closed line consisting of the imaginary axis from $-\infty$ to $+\infty$ and an infinite half-circle enclosing the right half of the "s"-plane is mapped on to the "G"-plane. For the system to be stable, this curve, called the NYQUIST plot or transfer locus, must not pass through or encircle the point $(-1, 0)$ of the "G"-plane.

Fig. 4 shows as an example the transfer locus of

$$G(s) = \frac{k}{s^2+(a+b)s+ab} = \frac{k}{(s+a) \cdot (s+b)}$$
$$(k, a \text{ and } b > 0).$$

The open loop is stable, since the denominator has negative real roots, $-a$ and $-b$. Assuming $k = 1$, $a = 0.5$ and $b = 1$, the following table shows values of $G(s)$ corresponding to a number of "s"-values along the "y"-axis.

s	$\pm\infty$	$\pm 4j$	$\pm j$	$\pm 0.5j$	0
$G(s)$	$-0 \mp 0.j$	$-0.056 \mp 0.022j$	$-0.2 \mp 0.6j$	$\mp 0.4 \mp 1.2j$	$+2$

It can be seen that the heart-shaped curve representing the NYQUIST plot of the system does not pass through or encircle the point $(-1, 0)$ of the "G"-plane; the system, therefore, is stable.

Frequency Response Function

The response of a linear system to a purely sinusoidal input is also sinusoidal and is of the same frequency. Representing a sinusoidal input function in an exponential form, $\theta_i(t) = a.e^{j\omega t}$, the response or output function is obtained by multiplying the input function with the frequency response function. This is itself a complex number which can similarly be represented in an exponential form as $F(\omega) = b.e^{j\psi}$, where b and ψ are functions of ω. The output, thus, is $\theta_o(t) = a.b.e^{j(\psi+\omega t)}$.

For any given frequency, the response is completely described by the gain b (or attenuation $\frac{1}{b}$) and the phase shift ψ; phase advance if positive or phase lag if negative.

Any element of a process control loop can be characterised or its dynamic behaviour be described by its frequency-response analysis or the plotting of gain and phase shift against frequency. The responses of several elements of a control loop (provided they do not interact) can be easily synthesised by multiplying the gains and adding up the phase shifts. In particular, if the plant response has been established and the response characteristics of a controller for various settings are known, the controller settings required to obtain stable or optimal control can be determined as explained below.

Plant elements can usually be considered as attenuators with phase lag, i.e., an applied sinusoidal input will produce an output of smaller amplitude, lagging in phase. The response of a controller, on the other hand, is that of an amplifier with phase advance.

Sustained oscillation or "hunting" will occur in a closed loop if the overall phase shift is zero or a multiple of 360

degrees and the overall gain equal to unity, or controller gain equal to plant attenuation. For the loop to be stable, the overall gain at an overall phase shift of 0 or $2\pi n$ must be less than unity.

Frequency Response of Plant Elements

The lags encountered in plant elements are essentially of two different kinds:

(a) Distance-velocity (DV) lags (sometimes also called transportation lags) are due to the time it takes for a material medium carrying the input change to travel from the point of input to the point of output. A DV lag is equal to the distance between input and output points divided by the velocity of travel. Its frequency response is given by:

$$\text{Attenuation } A = 1 \qquad \ldots.(13)$$

$$\text{Phase lag } \psi = \omega L \qquad \ldots.(14)$$

where L denotes the lag in time units.

(b) Transfer or resistance-capacity (RC) lags are exponential lags due to the resistance of the element to the transfer of the variable from an input to an output capacity. Although the time of complete transfer is theoretically infinite, transfer lags are measured in units of time constants, which may be described as the time the complete transfer would take if its initial rate were maintained. The frequency response of a transfer lag element of time constant T is given by:

$$\tan \psi = \omega T \text{ or } \psi = \tan^{-1} \omega T \qquad \ldots.(15)$$

$$A = \sqrt{1 + \tan^2 \psi} = \sec \psi \qquad \ldots.(16)$$

From Equation (15) it follows that, however large the time constant, the phase shift of a single RC lag element cannot exceed 90 degrees. In a succession of RC elements, the phase shifts are additive, whereas the combined attenuation is the product of the individual attenuations. A two-stage RC plant will, therefore, have a phase lag limit of 180 degrees, a three-stage RC plant 270 degrees, and so on.

A convenient method of representing the frequency response of a system graphically is by means of a polar diagram. In this, the length of the polar vector represents the attenuation, and the angle with the positive x-axis the phase shift for any given frequency; the locus of the response vectors is marked or scaled in frequency units. Fig. 5 shows the polar diagrams of a number of characteristic plants. Curve A, a circle with unit radius, is the response locus of a DV element, the straight line B that of a single-stage RC element, curves C, D and E those of two-, three- and four-stage elements.

(To be continued)

Symbols Used

θ = process variable;
θ_i = input value of θ;
θ_o = output value of θ;
$\theta_e = \theta_i - \theta_o$ = deviation or error signal;
$\Theta = \mathcal{L}[\theta]$ = Laplace transform of θ;
ω = angular frequency;
$-\alpha$ = damping factor;
$s = \alpha + j\omega$ = complex frequency;
$F(s)$ = Laplace transform of $f(t)$;
ψ = phase shift;
A = attenuation;
$G = \frac{1}{A}$ = gain;
L = distance-velocity (DV) lag;
T = time-constant of resistance-capacity or transfer (RC) lag;
m = proportional-control factor, nominal (controller setting);
s = integral action time, nominal (controller setting);
r = derivative action time, nominal (controller setting);
f = interaction factor;
u = proportional-control factor, actual = $f.m$;
S = integral action time, actual = $f.s$; and
R = derivative action time, actual = $\frac{r}{f}$

B.H.C.'s Expansion at Grangemouth

ON OCTOBER 17, the Rt. Hon. John Maclay, Secretary of State for Scotland, drove the first pile of a new, and third, ethylene plant which is the latest expansion project at present being undertaken by British Hydrocarbon Chemicals Ltd. at Grangemouth. The new plant is scheduled to be completed by the middle of 1960 and will cost, with its associated services and utilities, some £6 million. It will be similar to the two existing ethylene crackers and it will more than double British Hydrocarbon's output of olefins, adding a further 70,000 tons a year of ethylene which, it is believed, will make it the largest such plant outside the United States and considerably bigger than any similar plant so far planned in Europe.

Production of ethylene and other olefins commenced at Grangemouth in 1951, and was expanded in 1956 with the completion of a second unit. The additional ethylene produced by the new plant will enable existing utilisation plants, and the "Rigidex" polyethylene plant now under construction at Grangemouth, to be operated at full capacity. Sufficient ethylene and other olefins will also become available to enable a possible further programme of development to be undertaken.

The new plant is to be built on the Bo'ness Road expansion site opposite the existing works, to which it will be linked by underground lines. With the completion of the project, and of the polyethylene and phenol plants now under construction (to be completed during 1959), the total investment by the company will amount to over £30 million. British Hydrocarbon Chemicals Ltd. is a joint enterprise of The British Petroleum Co. Ltd. and The Distillers Co. Ltd., and in his speech to the guests attending the opening ceremony, MR. J. M. PATTINSON, chairman, said that his company was now putting a greater quantity of oil into chemical manufacture each year than the quantity of crude oil processed annually at Grangemouth refinery before the war. At that time the refinery handled a quarter of a million tons of oil a year. The input of feedstock to the existing B.H.C. ethylene plants is upwards of 400,000 tons a year, and after this new expansion is completed it will be doubled.

British Hydrocarbon Chemicals' plant at Grangemouth, showing the butadiene plant in the foreground and the tetramer plant behind.

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SIMPLIFIED METHOD FOR THE DESIGN OF BATCH DISTILLATION COLUMNS

A simplified method of calculating batchwise binary distillation, supported by experimental results, which takes account of hold-up

by Dr. ASGHAR HUSAIN, M.Sc., B.S.E.

THE complications of the mathematical treatment of batchwise fractionation have been briefly reviewed by HOUTMAN and the author in a previous paper.[1] It was shown that for the calculation of distillation conditions necessary for a given separation, the direct method based on ZUIDERWEG's equation[2] is most convenient. But this method can only be used where (a) relative volatilities of the components may be assumed constant over the range of compositions involved and (b) a relatively sharp separation is possible. Other methods given[3] require a laborious trial-and-error procedure, since these are in fact developed for calculating the batch distillation curves* when conditions are known.

The present paper describes a simplified method suggested by HOUTMAN and the author[4] as part of an educational scheme; the results reported are for a mixture of carbon tetrachloride and benzene. They show a close agreement between the required and experimental values of yield and composition of a desired fraction at 4 to 5% starting hold-up. From the practical point of view, however, it is more interesting to check this simple calculation method for wider boiling mixtures and for increased hold-up-to-charge ratios; this is the purpose of the present study.

Simplified Method

In this method the first step is to settle the operating requirements in terms of purity and yield of the more volatile component in the first fraction. The effect of hold-up is entirely neglected; it is then assumed that part of the distillation curve representing the desired fraction is a completely horizontal line, with an ordinate equal to the average desired composition of the fraction. Although this assumption is not strictly true, it enables us to select a certain point in the horizontal line which represents a combination of the distillate and bottom liquid compositions. These values can then be used as a basis for the calculation of reflux ratio and number of theoretical plates by the MCCABE-THIELE graphical procedure.[5]

Symbols Used

- A = mol. of required fraction to be used as basis of calculation;
- A' = actual mol. of required fraction;
- H = total mol. of hold-up or as mole-fraction of charge;
- N = total number of theoretical plates in the column;
- R = reflux ratio;
- x = mole-fraction of more volatile component in the bottom liquid;
- x_0 = mole-fraction of more volatile component in the charge;
- x_D = mole-fraction of more volatile component in the distillate;
- Y_a = actual yield of more volatile component;
- Y_r = required yield of more volatile component; and
- α = relative volatility.

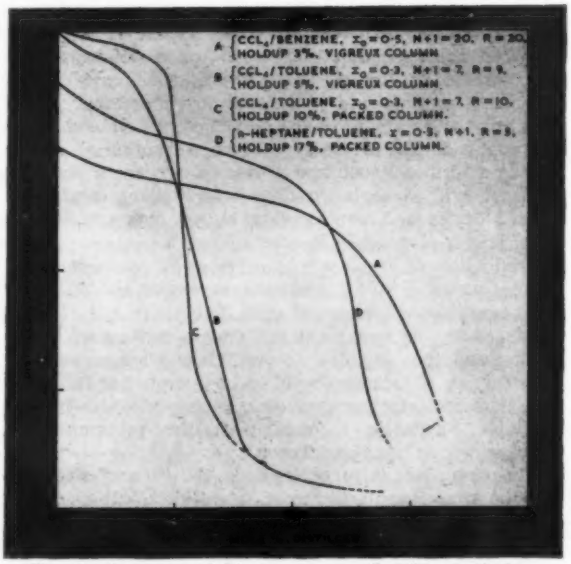
A
CCl₄/BENZENE, x₀ = 0·5, N+1 = 20, R = 20,
HOLDUP 3%, VIGREUX COLUMN
B
CCl₄/TOLUENE, x₀ = 0·3, N+1 = 7, R = 9,
HOLDUP 5%, VIGREUX COLUMN
C
CCl₄/TOLUENE, x₀ = 0·3, N+1 = 7, R = 10,
HOLDUP 10%, PACKED COLUMN.
D
n-HEPTANE/TOLUENE, x = 0·3, N+1, R = 5,
HOLDUP 17%, PACKED COLUMN.

Fig. 1. A group of binary curves showing variation of distillate composition with percent distilled.

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* In batch distillation it is a common and useful practice to represent the results in the form of a curve, obtained by plotting the amount of distillate or the amount of liquid left in the bottom versus instantaneous composition of the distillate.

Table I

	Column inside diameter (mm)	*Overall length (cm)*
Vigreux large*	18	236
Vigreux small	17	117
Packed with 6-mm Berl saddles	19	75 (packed height)

* Boil-up rate 15 g./min.

If the end point of the horizontal line is chosen as the reference point, then in the case of negligible hold-up the reflux ratio and number of theoretical plates thus calculated will give a better separation than required; this effect will become stronger if hold-up is found beneficial for separation. On the other hand, if hold-up is detrimental, it may possibly offset the advantageous effect gained by the use of the calculation method. In order to test the usefulness of this method, and to gain more insight into the proper selection of the reference point in view of the effect of hold-up, it was deemed necessary to determine experimentally the distillation curves for a number of mixtures over a wide range of operating conditions.

Experimental Work

The curves were determined for four mixtures, carbon tetrachloride-benzene, n-heptane-toluene, benzene-n-heptane and carbon tetrachloride-toluene representing a wide range of relative volatility ($\alpha = 1.1$ to 2.8), for hold-up-to-charge ratios ranging from 3 to 17 mol %, composition of charge 30 to 50 mol % of more volatile component, and reflux ratio 5 to 20. Three glass columns were used, two of the VIGREUX type and the third was packed with Berl saddles; the dimensions are given in Table I. They consisted of a number of theoretical plates 3 to 19, as determined under total reflux with the different mixtures used.

In order to obtain adiabatic operation, each column was enclosed in an inner jacket on which a heating coil with an underlayer of asbestos strips was evenly wound. The inner jacket was then surrounded by another jacket. The convection of air in the vertical direction within each space was partly checked by inserting cork baffles. In order to maintain a good adiabatic operation, the necessary temperature difference between the inner jacket and condenser was determined beforehand by running an experiment at zero reflux and comparing compositions of the distillate and that of bottom liquid.

The reflux-regulator consisted of a small vessel (containing a stainless-steel piece for reducing its inner volume) attached at the bottom with a number of vertical capillary tubes of different diameters but of equal lengths. By properly selecting the tubes for the conveyance of the reflux and drawing off the product, it was possible to maintain different reflux ratios. The regulator was checked beforehand at various distillate levels in the vessel and was found satisfactory. It was completely covered with thin metal sheet to equalise the temperature differences and was insulated with magnesia-asbestos. The reflux liquid was introduced into the column through a glass coil placed in the vapour line, so that it might be heated to the condensation temperature by up-coming vapour before falling inside the column. The vapour line was heated externally by a separate heating coil in order to prevent condensation and formation of extra reflux.

The number of theoretical plates was determined in each column under total reflux, either using a close boiling mixture like carbon tetrachloride-benzene or one of the mixtures. For each column and the mixture distilled in it, an estimate was made regarding the total moles of hold-up from a knowledge of previously determined volumetric hold-up of the column. The amount of the charge was adjusted accordingly to give desired hold-up-to-charge ratios. According to the advice given by ZUIDERWEG,[2] care was taken that at the start of each run the number of moles of lower boiling component in the bottom liquid were more than twice the moles of hold-up; this precaution is necessary to avoid any strong effect upon the distillation curves through starting up under total reflux. Once each run was started it was continued till the end.

Every possible care was taken to avoid losses due to leakage and vaporisation. All the joints were properly closed with an insulation insoluble in the liquids. At the end of each run an overnight period was allowed for the static hold-up to return, after which the material balance was checked. The losses were not proportional to the

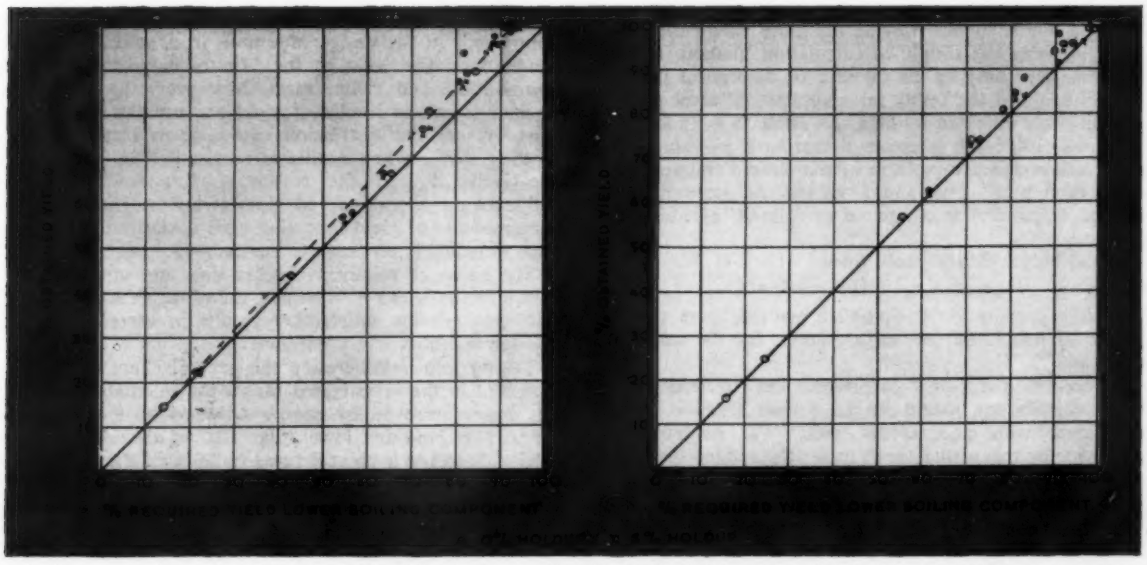

Fig. 2. Comparison of estimated yields with those actually obtained—hold-up 0 and 3%. Fig. 2a (right). Comparison showing improvement in method when A′ is made = A/0.9.

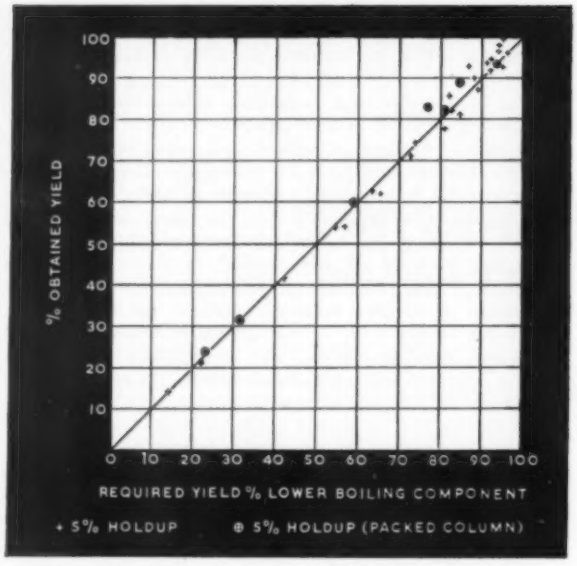

Fig. 3. Comparison of actual yield with desired yield.

charge and length of time required for the distillation; therefore, it was concluded that they did not arise from leaks in the column but were caused by failure to recover all the static hold-up.

Distillate fractions were collected at regular intervals and their compositions were checked by measuring refractive indexes at 35°C. Fig. 1 shows some of the determined distillation curves; great care was taken in drawing these so as to make them as smooth and representative as possible.

Since it was felt that accuracy of the calculation method should be related to the choice of requirements, the following procedure was used for checking all the experimental curves, and also zero hold-up curves calculated for different mixtures by RAYLEIGH's equation[6] and the MCCABE-THIELE method.[5]

Checking Procedure

A number of requirements for a certain mixture are deduced which should provide the same values for N and R when using the simplified calculation method. For this purpose, according to the number of theoretical plates in the column and the reflux ratio applied, different pairs of x_D and x are obtained by MCCABE-THIELE's method for all mixtures distilled. It is assumed that each x_D value represents an average composition of the desired fraction. Then from each pair of x_D and x values, the amount of the desired fraction A is computed as follows, assuming zero hold-up.

If the charge is 100 mol., then

$$100\,x_o = A\,x_D + (100 - A)\,x$$

In fact, according to the simplified method, these values of A and x_D should be the starting points for the calculation of N and R.

In each case $Ax_D = Y_r$ represents the required yield of more volatile component in the desired fraction. This is compared with the actual yield Y_a, experimentally obtained, by measuring area* under the related distillation curve up to the corresponding amount of A. $(Y_a - Y_r) \cdot 100/Y_r$ is the percentage deviation in the required yield.

The results of all calculations are arranged in Tables II to VII (and are further plotted in Figs. 2 to 5 in the form of percentage yield required versus obtained yield of the lower boiling component). It is clear that for a wide range of distillate compositions for all mixtures tested ($\alpha = 1.1$ to 2.8), the deviations in the obtained yield of lower boiling component generally fall, with very few exceptions, within $\pm 10\%$ depending upon the effect of hold-up, and possibly to some extent upon the change of H.E.T.P. with load and reflux ratio. In principle, the simplified method provides better conditions than required; the beneficial effect of hold-up increases the scope of this advantage, while the detrimental effect offsets it to such an extent that in a number of cases it brings down the deviations to the minus side. As evident from the results, almost all the deviations are on the positive side for 0 to 3% hold-up, while between 3 to 5% they are minor, and for greater hold-ups they are more on the negative side, particularly in the case of the VIGREUX column. In view of this tendency, the following improvements can be suggested in the method.

For hold-up lower than 3%, instead of using the end-point of the horizontal line a point before this one should be selected as the basis for calculating N and R. Similarly, for hold-up values as high as 10 to 15% a point after the end-point should be chosen so as to reckon the detrimental effect of the hold-up.

In order to be able to use the same experimental distillation curves for checking the improved calculation method, a new desired fraction is defined as A' mol. For 0 to 3% hold-up it is taken as $A' = A/0.9$, and for 10 to 15% hold-up as $A' = 0.9A$. In case of a close boiling mixture of carbon tetrachloride and benzene, the detrimental effect of hold-up is so great, even from 7%, that a point given by $A' = 0.9A$ does not help in bringing down the deviations. In such a case, therefore, $A' = 0.8A$ has been used. With these values of A', new values of Y_r and Y_a are computed in the same manner as above. The new deviations found are given in Tables VIII to XIIa (while Figs. 2a to 5a show the percentage yield required plotted versus obtained yield). For proper ranges of distillate composition for all mixtures, the close agreement (within $\pm 5\%$) is self-evident.

Conclusions

The simplified method developed for the calculation of N and R, though approximate in character, gives satisfactory results within $\pm 10\%$ in the yield of more volatile component in the desired fraction, in a sufficiently wide range of relative volatility, hold-up-to-charge ratio, charge composition and reflux ratio. Moreover, the maximum deviations in the results of yield are usually found in a range where the distillation curves show strong change in their slope. When distillates represented by these parts are included into the respective first fractions, they influence the overall compositions seriously. Therefore, the requirements of yield involving high deviations are of the least practical importance to the designer.

The value of relative volatility does not enter calculation directly. It can be expected, therefore, that the method will also provide satisfactory results in cases where the relative volatility is not constant.

Taking into consideration the general effect of hold-up observed in the investigated range, the calculation method has been improved by proper selection of the reference point. For hold-ups lower than 3% of the charge, it is advisable to use a point defined by 90% of the amount of desired fraction ($A = 0.9A'$) for the calculation of N and R: such a selection will minimise the advantageous effects gained both from the method and hold-up. In the range 3 to 5% hold-up, generally no correction is required, while for 5% or greater it is more safe to use a point defined by 10% increase in the amount of desired fraction ($A =$

* All areas under curves were accurately measured using an ALLBRIT planimeter.

Table II

CCl_4/benzene, $x_o=0.5$, $N+1=20$, $R=20$, $A=\frac{50-100x}{x_D-x}$ mol.
Large Vigreux column, charge=100 mol.

x_D	x	A	$Y_r=Ax_D$	Y_a for hold-up values				
				0%	3%	5%	7%	9%
0.715	0.46	15.7	11.23	11.35	11.31	11.07	10.75	10.91
0.70	0.412	30.6	21.38	21.88	21.46	20.75	19.64	19.67
0.68	0.34	47.1	32.02	33.43	33.13	31.17	28.90	28.60
0.665	0.30	54.8	36.44	38.56	37.80	35.53	33.00	32.54
0.632	0.25	65.4	41.33	44.73	43.82	41.23	38.28	37.62
0.60	0.22	73.7	44.22	48.01	47.60	44.95	41.99	41.23

Table IIa

x_D	Required % yield lower boiling	(Y_a-Y_r) 100/Y_r for hold-up values				
		0%	3%	5%	7%	9%
0.715	22.5	1.1	0.7	—1.4	—4.3	—2.8
0.70	42.8	2.3	0.4	—2.9	—8.1	—8.0
0.68	64.0	4.4	3.4	—3.2	—9.7	—10.7
0.665	72.9	5.8	3.7	—2.5	—9.4	—10.7
0.632	82.7	8.2	6.0	—0.2	—7.4	—9.0
0.60	88.4	8.5	7.6	+1.6	—5.0	—6.8

Table III

n-Heptane-Toluene, $x_o=0.322$, $N+1=20$, $R=17$, $A=\frac{32.2-100x}{x_D-x}$ mol. Large Vigreux column, charge=100 mol.

x_D	x	A	$Y_r=Ax_D$	Y_a for hold-up values			
				0%	5%	10%	15%
0.92	0.271	7.8	7.18	7.24	6.99	7.28	7.32
0.91	0.174	20.1	18.29	18.57	17.32	17.75	18.05
0.90	0.144	23.5	21.15	21.65	20.01	20.37	20.73
0.85	0.072	32.1	27.28	29.08	26.11	26.00	26.53
0.80	0.055	35.8	28.64	30.99	28.06	27.80	28.41
0.70	0.048	42.0	29.40	32.19	30.19	29.84	30.33

Table IIIa

x_D	Required % yield lower boiling	(Y_a-Y_r) 100/Y_r for hold-up values			
		0%	5%	10%	15%
0.92	22.3	0.8	—2.6	1.4	1.9
0.91	56.8	1.5	—5.3	—3.0	—1.3
0.90	65.7	2.3	—5.4	—3.7	—2.0
0.85	84.7	6.6	—4.3	—4.7	—2.7
0.80	88.9	8.2	—2.0	—2.9	—0.8
0.70	91.3	9.5	+2.7	+1.5	+3.2

Table IV

Benzene/*n*-Heptane, $x_o=0.3$, $N+1=7$, $R=9$, $A=\frac{30-100x}{x_D-x}$ mol.
Large Vigreux column, charge = 100 mol.

x_D	x	A	$Y_r=Ax_D$	Y_a for hold-up values		
				0%	5%	10%
0.90	0.270	4.8	4.32	4.32	4.26	4.25
0.80	0.081	30.4	24.32	26.30	23.37	23.59
0.70	0.055	38.0	26.60	29.30	26.14	—
0.60	0.043	46.1	27.66	29.96	27.63	—

Table IVa

x_D	Required % yield lower boiling	(Y_a-Y_r) 100/Y_r for hold-up values		
		0%	5%	10%
0.90	14.4	0	—1.4	—1.6
0.80	81.1	8.1	—4.3	—3.0
0.70	88.7	10.2	—1.7	—
0.60	92.2	8.3	—0.1	—

Table V

CCl_4/Toluene, $x_o=0.3$, $N+1=7$, $R=9$, $A=\frac{30-100x}{x_D-x}$ mol.
Small Vigreux column, charge=100 mol.

x_D	x	A	$Y_r=Ax_D$	Y_a for hold-up values				
				0%	3%	5%	10%	15%
0.96	0.162	17.3	16.61	17.03	16.68	16.34	15.94	16.04
0.90	0.102	24.8	22.32	24.40	23.20	22.29	21.74	21.56
0.80	0.078	30.7	24.56	28.14	26.06	25.72	24.93	24.74
0.70	0.062	37.3	26.11	—	28.28	27.97	26.80	26.63
0.60	0.051	45.4	27.24	—	28.90	28.92	27.50	27.07

Table Va

x_D	Required % yield lower boiling	(Y_a-Y_r) 100/Y_r for hold-up values				
		0%	3%	5%	10%	15%
0.96	55.3	1.9	0.4	—1.6	—4.0	—3.4
0.90	74.4	9.3	3.9	—0.1	—2.6	—3.4
0.80	81.9	14.5	6.1	+4.7	+1.1	+0.7
0.70	87.0	—	8.3	7.1	2.6	2.0
0.60	90.8	—	6.1	6.2	0.9	—0.6

$A'/0.9$); such a correction will take care of the possible detrimental effect of hold-up. In the case of close boiling mixtures, like that of carbon tetrachloride and benzene, it will be necessary to use a point given by $A = A'/0.8$, or maybe more, for greater hold-ups. In fact, for the results obtained with the packed column for greater values of hold-up, no correction is required, since the effect of hold-up in the investigated range is not detrimental but, if anything, beneficial. Therefore, if one applies a correction without prior knowledge of the behaviour of a certain column, it will provide a safety margin and yield a product of greater purity. Afterwards, either the conditions can be maintained or adjusted with a proper decrease in the reflux ratio. As evident from Tables XII and XIIa, even after

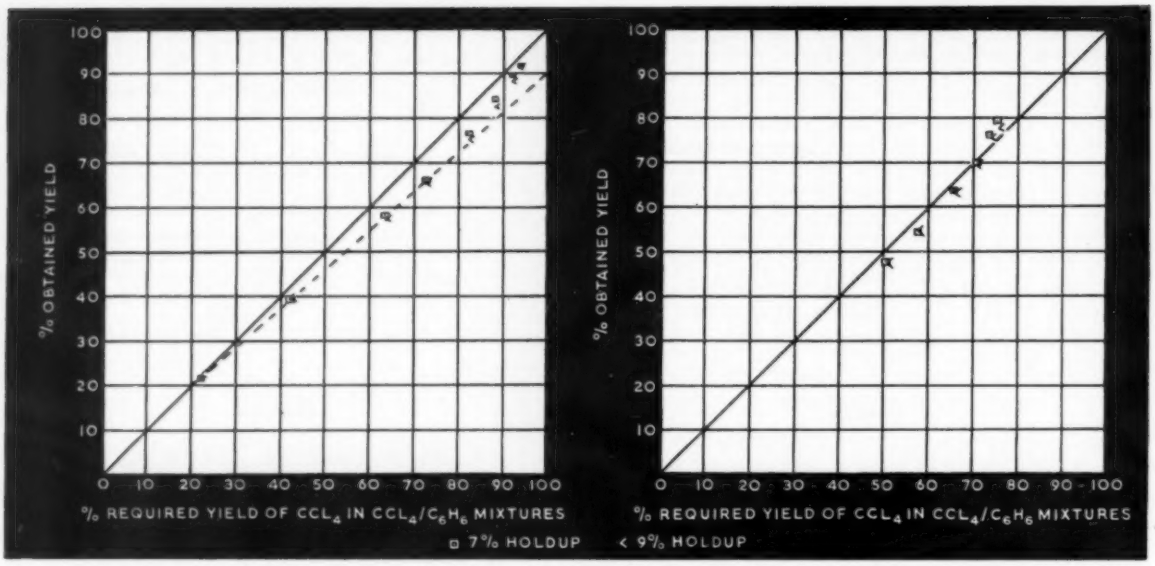
% OBTAINED YIELD
% REQUIRED YIELD OF CCL_4 IN CCL_4/C_6H_6 MIXTURES
□ 7% HOLDUP
% OBTAINED YIELD
% REQUIRED YIELD OF CCL_4 IN CCL_4/C_6H_6 MIXTURES
< 9% HOLDUP

Fig. 4. Experimental and desired yields of CCl_4 in CCl_4-C_6H_6 systems for 7% and 9% hold-up. Fig. 4a (right). Agreement improved by making A′ = 0.8A.

applying the correction ($A = A'/0.9$) to the packed-column results for 10 and 17% hold-up, the deviations are still within 10% in the high range of distillate compositions.

The use of the method is illustrated by the following examples.

Example 1

A mixture of carbon tetrachloride and toluene, initial composition 30 mol. % carbon tetrachloride, is to be fractionated batchwise to produce a distillate fraction of composition 96 mol. % carbon tetrachloride, and containing 61.4% of carbon tetrachloride present in the original mixture. The initial hold-up ratio will be 0 to 3%.

Charge = 100 mol.

Required yield carbon tetrachloride = (30) (0.614) = 18.42 mol. in the fraction

Required amount of fraction $A' = 18.42/0.96 = 19.2$ mol.

Amount of fraction to be used as basis of calculation

$$A = (19.2)\ (0.9) = 17.3 \text{ mol.}$$

From A and x_D the bottom composition can be calculated as follows, assuming zero hold-up;

$(100)\ (0.3) = (17.3)\ (0.96) + (100 - 17.3)x$; $x = 0.162$.

With the values of $x_D = 0.96$ and $x = 0.162$, a suitable operating line can be chosen on a McCabe-Thiele diagram,* so that these two points are related with a certain reflux ratio and number of theoretical plates. For an

* Batch distillation is mostly carried out in the packed columns, which are the easiest to construct and least expensive. In the case of these columns the use of the McCabe and Thiele method is open to criticism because the calculation of the number of theoretical plates on a McCabe-Thiele diagram is a stepwise procedure, whereas the process in a packed column is continuous. Because of this fundamental difference, Chilton and Colburn[9] have proposed use of the transfer unit concept. Although this concept is more rigorous, since it is based on a differential treatment of the column conditions, the theoretical plate method is easier to use.

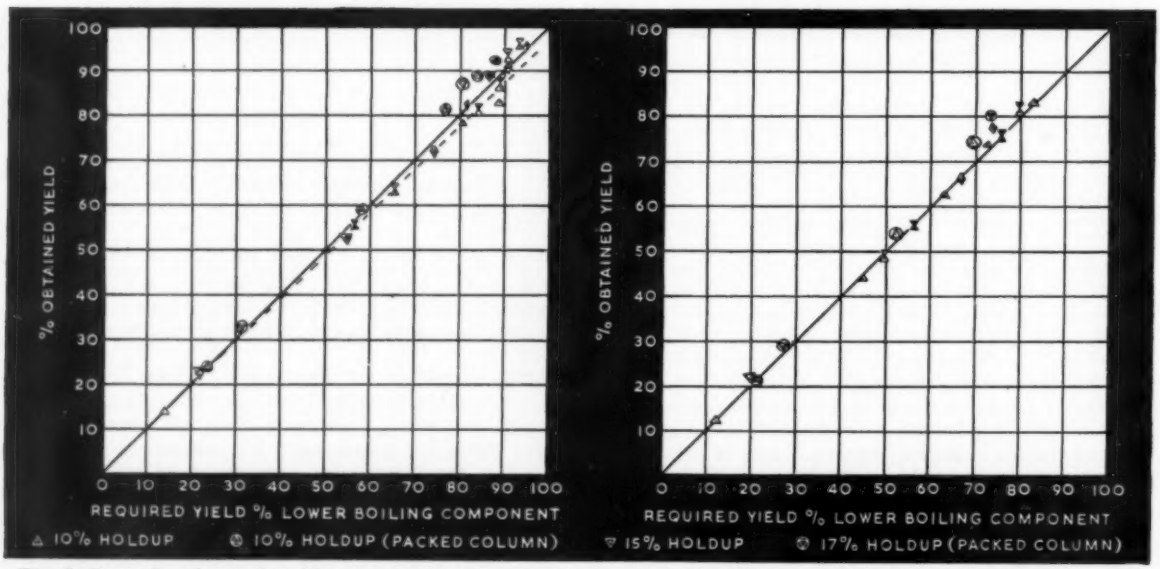
% OBTAINED YIELD
REQUIRED YIELD % LOWER BOILING COMPONENT
△ 10% HOLDUP
◎ 10% HOLDUP (PACKED COLUMN)
% OBTAINED YIELD
REQUIRED YIELD % LOWER BOILING COMPONENT
▽ 15% HOLDUP
◎ 17% HOLDUP (PACKED COLUMN)

Fig. 5. Desired and actual yields for mixtures where hold-ups are 10%, 15%, and 17% Fig. 5a (right). Improved agreement when A′ is made = 0.9A.

Table VI

CCl_4/Toluene, $x_o=0.3$, $N+1=7$, $R=10$, $A=\frac{30-100\,x}{x_D-x}$

Packed column, charge=100 mol.

x_D	x	A	$Y_r=Ax_D$	% required yield	Ya for hold-up values		% deviation for hold-up values	
					5%	10%	5%	10%
0.98	0.247	7.2	7.06	23.5	7.14	7.14	1.1	1.1
0.96	0.152	18.3	17.57	58.6	18.06	17.90	2.7	1.8
0.90	0.093	25.7	23.13	77.1	24.86	24.51	7.5	6.0
0.80	0.069	31.6	25.28	84.3	26.74	26.79	5.7	6.0

Table VII

n-Heptane/Toluene, $x_o=0.5$, $N+1=12$, $R=5$, $A=\frac{50-100\,x}{x_D-x}$ mol.

Packed column

x_D	x	A	$Y_r=Ax_D$	% required yield	Y_a for hold-up		% deviation for hold-up	
					5%	17%	5%	17%
0.8	0.426	19.8	15.84	31.7	16.07	16.44	1.4	3.7
0.7	0.227	57.7	40.39	80.8	41.35	43.73	2.4	8.0
0.6	0.149	77.8	46.68	93.4	46.83	—	0.3	—

Table VIII

CCl_4/C_6H_6, $x_o=0.5$, $N+1=20$, $R=20$, Vigreux column

x_D	A	$A'=A/0.9$	$Y_r=A'x_D$	% required yield	Y_a for hold-up values		% deviation for hold-up	
					0%	3%	0%	3%
0.68	47.1	52.3	35.56	71.1	36.95	36.26	3.9	2.0
0.665	54.8	60.9	40.50	81.0	42.29	41.37	4.4	2.1
0.632	65.4	72.7	45.95	91.9	47.86	47.21	4.1	2.7

Table VIIIa

x_D	A	$A'=0.8A$	$Y_r=A'x_D$	% required yield	Y_a for hold-up values		% deviations for hold-up	
					7%	9%	7%	9%
0.68	47.1	37.7	25.64	51.3	23.68	23.59	—7.6	—8.0
0.665	54.8	43.8	29.13	58.3	27.09	26.86	—7.0	—7.8
0.632	65.4	52.3	33.05	66.1	31.69	31.27	—4.1	—5.4
0.60	73.7	59.0	35.40	70.8	35.1	34.56	—0.8	—2.3

Table IX

n-Heptane/Toluene, $x_o=0.322$, $N+1=20$, $R=17$, Vigreux column

x_D	A	$A'=A/0.9$	$Y_r=A'x_D$	% required yield	Y_a zero hold-up	% deviation
0.92	7.8	8.7	8.00	24.8	8.09	1.1
0.90	23.5	26.1	23.49	73.0	23.97	2.0
0.85	32.1	35.7	30.34	94.2	30.96	2.0
0.80	35.8	39.8	31.84	99.0	31.92	0.2

Table IXa

x_D	A	$A'=0.9A$	$Y_r=A'x_D$	% required yield	Y_a for hold-up values		% deviation for hold-up	
					10%	15%	10%	15%
0.92	7.8	7.0	6.44	20.0	6.54	6.57	1.5	2.0
0.90	23.5	20.2	18.18	56.6	17.75	18.05	—2.5	—0.9
0.85	32.1	28.9	24.56	76.3	24.11	24.56	—1.8	0
0.80	35.8	32.2	25.76	80.0	26.00	26.53	+0.9	3.0

Table X

Benzene/*n*-Heptane, $x_o=0.3$, $N+1=7$, $R=9$, Vigreux column

x_D	A	$A'=\frac{A}{0.9}$	$Y_r=A'x_D$	% required yield	Y_a for zero hold-up	% deviation
0.9	4.8	5.3	4.77	15.9	4.77	0
0.88	17.1	19.0	16.72	55.7	16.96	1.4
0.85	24.9	27.7	23.54	78.5	24.30	3.2
0.80	30.4	33.8	27.04	90.1	28.17	4.2
0.70	38.0	42.2	29.54	98.5	29.79	0.8

Table Xa

x_D	A	$A'=0.9A$	$Y_r=A'x_D$	% required yield	Y_a for 10% hold-up	% deviation
0.9	4.8	4.3	3.87	12.6	3.82	—1.3
0.88	17.1	15.4	13.55	45.1	13.30	—1.8
0.85	24.9	22.4	19.05	63.5	18.78	—1.4
0.80	30.4	27.4	21.92	73.1	22.12	+0.9

Table XI

CCl_4/Toluene, $x_o=0.3$, $N+1=7$, $R=9$, Vigreux column

x_D	A	$A'=\frac{A}{0.9}$	$Y_r=A'x_D$	% required yield	Y_a for hold-up		% deviation	
					0%	3%	0%	3%
0.96	17.3	19.2	18.43	61.4	18.83	18.45	2.2	0.1
0.90	24.8	27.6	24.84	82.8	26.46	25.18	6.5	1.3
0.80	30.7	34.1	27.28	90.9	29.45	27.47	8.0	0.7
0.70	37.3	41.4	28.98	96.6	—	28.73	—	—0.8

Table XIa

x_D	A	$A'=0.9A$	$Y_r=A'x_D$	% required yield	Y_a for hold-ups		% deviation for hold-up	
					10%	15%	10%	15%
0.96	17.3	15.6	14.98	49.9	14.48	14.60	—3.3	—2.5
0.90	24.8	22.3	20.07	66.9	19.97	19.89	—0.5	—0.9
0.80	30.7	27.6	22.08	73.6	23.43	23.22	+6.1	+5.1

Table XII

n-Heptane/Toluene, $x_o = 0.5$, $N+1 = 12$, $R = 5$, Packed column.

x_D	A	$A' = 0.9A$	$Y_r = A'x_D$	% required yield	Y_a for 17% hold-up	% deviation
0.8	19.8	17.8	14.24	28.5	14.87	4.4
0.7	57.7	51.9	36.33	72.7	40.10	10.3

Table XIIa

CCl_4/Toluene, $x_o = 0.3$, $N+1 = 7$, $R = 10$, Packed column

x_D	A	$A' = 0.9A$	$Y_r = A'x_D$	% required yield	Y_a for 10% hol-up	% deviation
0.98	7.2	6.5	6.37	21.2	6.45	1.3
0.96	18.3	16.5	15.84	52.5	16.18	2.1
0.90	25.7	23.1	20.79	69.3	22.39	7.7
0.80	31.6	28.4	22.72	75.7	25.91	14.0

economically sound and stable operation, it is always desirable to choose a combination of reflux ratio and the number of theoretical plates in a region where a change in one will not produce a relatively big change in the other in order to attain the same separation; in such combinations, values of both are numerically close to each other.[3, 7, 8] Thus selected, $N + 1 = 7$ and $R = 9$. Now a column should be used which will provide $N + 1 = 7$ under total reflux with the same mixture. After establishment of equilibrium at total reflux, the product must be drawn at a reflux ratio 9:1 up to the amount of the desired fraction. As evident from Table XI, in an actual run under the calculated conditions, the yield of carbon tetrachloride obtained at 3% hold-up is 0.1% higher than required, while the calculated zero hold-up curve gives a result 2.2% higher.

Example 2

The same mixture is to be fractionated to produce a distillate fraction containing 90 mol. % carbon tetrachloride, and 66.9% yield. The hold-up will be 10 to 15% of the charge.

$$A' = (30)\ (0.669)/0.9 = 22.3 \text{ mol.}$$

In this case $A = A'/0.9 = 22.3/0.9 = 24.8$ mol.

$(100)\ (0.3) = (0.9)\ (24.8) + (100-24.8)x$; $x = 0.102$.

With $x_D = 0.9$ and $x = 0.102$ selected, $N + 1 = 7$ and $R = 9$.

Actual yield obtained is 0.5 and 0.9% lower than that required at 10 and 15% hold-ups respectively. Afterwards a minor adjustment in the reflux ratio will provide the desired result.

Table XIII presents a comparison between the values of pole-height experimentally obtained and those calculated from ZUIDERWEG'S equation.[2] For the sharpest mixture of carbon tetrachloride-toluene, a good agreement is only obtained when $N + 1 = 4$ is inserted into the equation instead of $N + 1 = 7$, the former being the number of theoretical plates actually found with benzene-n-heptane mixture in the same column. The possible explanation is in the change of efficiency or H.E.T.P. of the column with change of reflux ratio from infinity to 9.

In the case of carbon tetrachloride-toluene mixture distilled in the packed column, and benzene-n-heptane mixture in the VIGREUX column, values of experimental pole-height are higher than the calculated ones. One reason may be the effect of total reflux start-up still present, though

Table XIII

Mixture	*R*	*H*	*Pole height*				*Remarks*
		Exp.	Exp.	Calc. $N+1=7$	Calc. $N+1=4$		Small Vigreux column
CCl_4/ toluene	9	0	3.7	7.2	3.8		$N + 1 = 7$ as obtained with CCl_4/toluene
		0.03	3.1	8.1	3.6		
		0.05	2.8	8.0	3.5		$N + 1 = 4$ as obtained with *n*-heptane/benzene
		0.10	3.0	7.1	3.0		
		0.15	2.8	5.9	2.7		
CCl_4/ toluene			Exp.	Calc. $N+1=7$	Calc. $N+1=12$	Calc. $N+1=9$	Packed column
							$N + 1 = 7$ as obtained with CCl_4/toluene
	10	0.05	10.5	8.7	12.9	10.6	
		0.10	9.4	7.5	12.2	9.5	$N + 1 = 12$ as obtained with CCl_4/benzene.
							$N + 1 = 9$ assumed
Benzene/ *n*-heptane			Exp.	Calc. $N+1=7$	Calc. $N+1=20$	Calc. $N+1=10$	Large Vigreux column
							$N + 1 = 7$ as obtained with benzene-*n*-heptane
	9	0.05	3.5	2.3	5.5	3.5	$N + 1 = 20$ as obtained with CCl_4/benzene.
		0.10	4.0	2.2	6.5	3.6	$N + 1 = 10$ assumed
			Exp.	Calc. $N+1=18$			
n-heptane/ toluene	17	0.05	3.3	3.9			Large Vigreux column
		0.10	2.1	4.0			$N + 1 = 18$ as obtained with the same mixture
		0.15	2.7	3.8			
			Exp.	Calc. $N+1=12$			
n-heptane/ toluene	5	0.05	1.3	1.0			Packed column
		0.17	1.5	1.2			$N + 1 = 12$ as obtained with the same mixture

this has been minimised in the beginning according to the direction of ZUIDERWEG.[3] Another possibility is that in the later part of the distillation, when distillate composition comes down to 50% or lower, a column containing a finite number of plates (as determined under total reflux) may operate very close to one containing a higher or infinite number of plates. In any case, ZUIDERWEG's equation seems to have more or less a general validity for different types of columns, though it is doubtful which value of N will provide the correct answer in such cases as presented above. In fact, the method of using the slope of the distillation curve at a particular point, or in turn the pole-height, as a criterion for sharpness of separation appears to be quite sensitive to small deviations in the curves. On the other hand, using composition and yield of a fraction, as used in the simplified calculation method, is not so susceptible to minor changes. Results presented in Tables II to XIIa show that the number of theoretical plates determined under total reflux with the mixture to be distilled can be safely used in the simplified method. Even in the case of less sharp separating mixtures, such as of n-heptane-toluene, it is sufficient to use the number of plates determined by a close boiling mixture of carbon tetrachloride-benzene. The total reflux start-up also has no appreciable influence upon the calculations.

The distillation of multi-component mixtures can be considered as consisting of a number of binary separations, if sharp separation is present. Such mutual independence in the separation of components can be noted in the distillation of the ternary mixture of n-heptane, methylcyclohexane, and toluene carried out by ROSE and O'BRIEN,[10] in which the separation between n-heptane and methyl cyclohexane was completely independent of the presence of toluene, the latter acting rather as a pushing liquid. This is also clear from the results of ZUIDERWEG.[3] In such cases calculations can be approximated by a number of binary separations using the simplified method.

ACKNOWLEDGMENT

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Dollar-saving Synthetic Rubber Plant

NOW that the International Synthetic Rubber Co. have their styrene-butadiene rubber plant at Hythe in full production, this country will not only be independent of overseas sources of this material, which were met formerly by imported rubber at a cost of over $25 million, but will also be able to export it in useful quantities.

The process is based upon the cold emulsion polymerisation of butadiene and styrene—a process which has already been well described in the literature[1] The plant, which ranks among the most modern of contemporary synthetic rubber plants, has in design benefited not only from overseas experience but also from the all-purpose pilot plant of the Dunlop Rubber Co.[2]

Cold emulsion polymerisation is carried out continuously and the reaction is allowed to proceed as far as 60% completion. This represents the best compromise of reactor costs, cost of recovery of unreacted polymers and product quality. The unreacted butadiene is recovered by evaporation in three stages of pressure reduction, the lowest pressure being 200 mm absolute. The styrene is then steam stripped at 40 mm Hg abs. in a 9-ft column containing 14 sieve trays. The sea-water-cooled condensers for the steam styrene vapours have duplex tubes and lead-lined shelves.

The subsequent processing of the latex may follow one of two paths. After the addition of anti-oxidant, the latex may be converted to crumb by successive treatment with brine and dilute sulphuric acid. The crumb is then filtered, washed, dried and compacted, or the coagulation may be preceded by the addition of an aromatic oil which, in conjunction with a latex of higher molecular weight, yields an extended rubber comparable to the unextended variety. But since the oil is cheaper than butadiene the product, containing as much as 30% by weight of oil, is correspondingly cheaper. The butadiene for the plant is piped from the nearby Esso Fawley refinery and styrene is transported by road, rail or sea from Firth Chemicals at Grangemouth and Shell Plant at Partington.

The International Synthetic Rubber Co. Ltd., Hythe
Details of the Process Plant

Cost of Constructing and Equipping Plant, inclusive of Site Clearance	£5,750,000
Number of Employees	400
Storage Facilities:	
Butadiene	120,000 Imp. Gal.
Styrene	240,000 Imp. Gal.
Process Oil	350,000 Imp. Gal.
Estimated Pipeline Mileage within Plant Boundaries (all liquids)	Over 50 miles
Annual Butadiene Consumption	50,000 tons approx.
Annual Styrene Consumption	13,000 tons approx.
Annual Fuel Oil Consumption	2,500,000 Imp. Gal.
Annual Electricity Consumption	25,000,000 kW
Annual Compressed Air Consumption ...	450,000,000 cu. ft

Sectional view of the International Synthetic Rubber Co.'s Hythe plant for recovering styrene from products of the polymerisation reaction.

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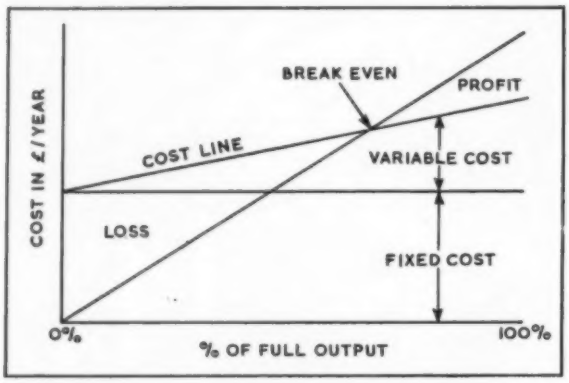
CHEMICAL ENGINEERING ECONOMICS

Tributes were paid by leading engineers to the Graduates and Students Section, Institution of Chemical Engineers, in organising a symposium on costing and allied topics. Some of the papers are summarised below

IT IS VERY OFTEN difficult to assess the economics of a plant until it has been running for a long time, said DR. J. W. WOOLCOCK, Technical Director, I.C.I. (Heavy Organic Chemicals) Ltd., in the opening paper to the Conference. After illustrating the point with several examples, he mentioned that in one case of a plant now operating it would not be known what the financial results were until 1970. Estimating has to take account of future trends, perhaps up to 20 or 25 years ahead. The procedure starts with an "expenditure proposal". This covers the complete project, including all quantities, technical details, capital costs, proposal for depreciation, how the product would expect to sell and the expected realisation.



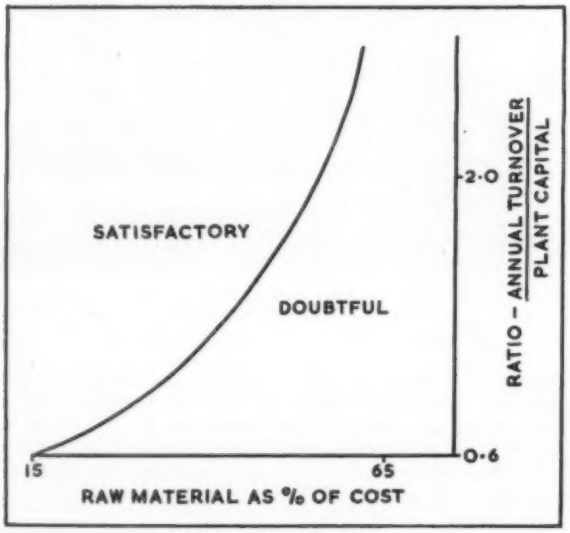


Fig. 1 (*top*) *and Fig.* 2.

It is useful to break down the cost into its components of fixed costs and costs varying with output. These are then plotted, the axes being percentage of full output versus pounds per year (Fig. 1). At the point where the total cost line crosses the returns line we have the break-even point, and output in excess of this percentage results in a profit. If the project is highly geared to raw material costs it is useful to plot the realisation on the product against the cost of raw materials. This kind of project is very dangerous; it is a pure gamble which it is better not to touch. On a graph of this sort, it is possible to draw in a line representing break-even conditions and then on either side of it parallel lines representing percentage profit and percentage loss. If these lines are closely spaced the project is undesirable, but in many cases the lines are widely spaced.

Another useful graph which can be drawn is one plotting raw material as a percentage of total cost against the ratio of annual turnover to that of plant capital (Fig. 2). This is an empirical relationship which has been found very useful in practice. In general, engineers need to be aware that studies of the commercial side are as important as those of the technical side of a project.

Price Order Assessment

IT WAS NOT POSSIBLE to present a learned paper on price order assessment, emphasised MR. J. P. ASQUITH, Manager, Engineering Division (Projects), W. J. Fraser; the subject did not have the precision of thermodynamics. The accuracy of an estimate depended on the time devoted to making it. At the earliest stage of a job all that is required is the order of prices. Even on this basis, however, the speaker was critical of statements in certain (particularly U.S.) journals of the accuracy of estimates by capital-cost ratio. This basis of estimating should only be used by people so experienced that they could in any case make the estimate by other means.

Cost depends on materials and space occupied and not particularly on the product. It is always useful to note prices with the date on which they were obtained in order to build up a background of knowledge for "refined guessing". After this stage comes detailed estimating. There is a remarkably constant relationship between costs over the following main items: (1) plant items; (2) pipe work and valves; (3) electrics; (4) instruments; (5) civil; (6) site work; and (7) engineering costs.

With a flow diagram it is possible to establish (1), but the others are probably difficult. A paper in *Chem. Eng.*, November, 1953, by KISTIN, CAMERON and CARTER, listed over 100 cost breakdowns for all the American World War II chemical factories. Thus a careful estimate of (1) could be used as the basis of the total estimate by scaling-up proportionately. This applies from one process to another, but it should be borne in mind that the cost of design is not a function of size or value of material. By experience, an engineer would get knowledge of prices even of plant which he had not personally worked on: with care, diligence and co-operation, information could be built up. MR. ASQUITH had found that even by simply asking at exhibition stands price information could often be obtained. This method of approach for first, quick estimating is a matter of giving signposts to follow in building up individual experience. There is no quick panacea.

In discussion, MR. BICKLE drew attention to the importance of services to the contractor, such as water, electricity, lavatory facilities and maintaining good access to the site. DR. WOOLCOCK, entering the discussion, spoke of the fact that quick estimates have a place for a first assessment of whether to proceed or not. Often, first inquiries are not followed up so that rapid techniques are valuable to avoid wasting time on fruitless inquiries. Estimates should be related to the purpose for which they are to be applied and the latter should be stated explicitly as well as the basis of estimation. The estimate of cost should also contain an estimate of its error.

MR. ASQUITH pointed to the advantage for financial control purposes of plotting against time the extent of commitment as well as that of expenditure. The first, of course, should rise very sharply and produce a characteristic pattern. Any deviation from this usual pattern would need careful reconsideration.

Centrifugal Fans and Pumps

MR. H. W. THORP, of the Chemical Engineering Department, University College, London, opened by discussing the factors involved in selecting a centrifugal fan for a specific duty and went on to give specific costs, taking as a basis a fan to handle 10,000 cu. ft per min. of clean cool air at 2.0 in. w.g. The approximate cost of a forward paddle blade impeller fan of speed 730 rpm and efficiency 60% would be £100. A backward blade fan at the same speed with 70% efficiency would be about £200, while an aerofoil section blade fan at the same speed at 80% efficiency would be £250. For cool, clean air multi-blade fans are smaller and better than other types. However, if there are dust- or mist-laden gases more robust construction will be needed to combat dangers of erosion, corrosion or build-up. The extra cost will be about 20%.

For cool, clean gases mild steel is adequate, but with very large fans high-tensile steel is needed for the impeller. The extra cost will be 15%. For corrosive gases a stainless-steel shaft impeller and casing may be needed and will multiply the cost by 4. However, if corrosive conditions permit the use of rubber or P.V.C. coating which only double the cost of mild steel.

The Vee belt is the cheapest method of drive. A direct-drive flexible coupling would multiply the cost by 1.15. Variable output may be obtained by a variable-speed motor at 2.5 times the cost of Vee belt drive or by fluid coupling at 1.75 times this cost. An inlet vane control would increase the cost to 1.5 times the original.

For centrifugal pumps the basis was taken as one handling clean water at 100 gal. per min. and 50-ft. delivery head. A 3-in. pump of all-cast-iron construction with a closed impeller and end suction would cost about £30; with a bronze impeller it would be £50. The efficiency at 1450 rpm is 60%. For slurries, sewage and the like a special robust type is needed with an open impeller and a front hinged for easy cleaning. With a 3-in. end-suction pump the efficiency at 1450 rpm is 45% and the cost roughly £110. This would be made with a high-tensile-steel shaft sleeved in stainless steel. For a chemical plant handling very corrosive liquids, pumps may be made of high-silicon iron at a cost of roughly three to four times that of ordinary pumps. If it is possible to use a rubber-covered impeller or enamelled iron the cost will be only double.

Direct-coupled pumps are almost universally used, since the motor and pump shaft can be aligned at the works. In special cases steam turbines can be used. For very large pumps, such as those handling 5000 gal. per min., vertical drive is used with the impeller mounted directly on the motor shaft.

Market Research

THE AIM OF MARKET RESEARCH applied to production planning is to provide facts where they can be found in order to supply them to management to reduce the area of unsupported judgment. An important part of it, stated MR. H. MUNT of the Marketing Research Division, Unilever Ltd., was assessing genuine trends in consumption, allowing for trends in stocks and not simply based on production trends. For production planning a company needs the following: (1) an estimate of the market in relation to cost; (2) an estimate of whether the market is expanding or contracting; (3) the position in respect of competition; (4) factors such as seasonal demand; and (5) production qualities required by users. A valuable guide to sources of trade information is the book "Statistical Sources for Market Research", 1957 (Oakwood Press). Survey work among distributors and consumers is well known, but it needs also to be carried out among manufacturers.

Instrumentation and Control Equipment

DR. D. W. GILLINGS, of the Central Instrument Laboratory, I.C.I. Ltd., gave a detailed paper with extensive tables of figures on the cost of process instrumentation and automatic control equipment. Opening with a general survey of divisions of instruments commonly used, he pointed out that a variety of types of measurements were usually transformed into signals controlling pneumatic transmission and eventually pneumatic control so that the movement of the indicating elements of different sorts becomes an air-pressure operating a control mechanism. Most control is exerted by a control valve on a fluid flow either of process material or a heating fluid. If it is considered adequate to work with only indicators, the cost is reduced, and if multiple recording on one instrument is practicable the expense is less per record than a single record. Pressure is a cheaper variable to deal with than temperature.

There can be a wide range of plant sizes requiring the same instrumentation. On a large plant it might represent 5% of the cost non-installed or 7% installed. Generally, 5% to 15% is the range in usual cases. There is now an increase in interest in the use of analytical equipment, although this is much more expensive than physical measurement. In addition, the trend is to the use of electronics in place of pneumatics, and there is now being introduced data-logging and the production of digital records leading up to a computer control equipment.

In discussion, DR. BERKOVITCH asked if this trend towards use of electronics was concerned with increasing reliability of electronic equipment. DR. GILLINGS replied that this was a part of the answer, but, in addition, there was a limit to the rate at which pneumatic controllers operate and the electronic ones were very much faster.

TABLE 1 (a)—Analysis giving Average Instrument Cost, %, Additions for Accessories and Installation and Probable Installed Cost Range

Type of Unit	*Base Cost*	*Add percentages for*		*Probable Installed Cost Range*
		Accessories	*Installation*	
	£			£
Differential flow indicator	100	65	15	160–200
Differential flow recorder	105	70	25	180–220
Pressure recorder	45	30	20	over 80
Temperature recorder (bulb)	70	30	18	110–130
Potentiometric recorder (1 record)	180–250	15	10	230–300
Potentiometric recorder (6 record)	300–500	45	20	450–750
Pneumatic control (components and accessories)	110	—	45	150 upwards
Pneumatic transmission (components and accessories)	85	—	25	100 upwards
Control valve (per 1 in. of dia.)	60	50	30	100 upwards

* System includes pneumatic pipework, 1-in. valve (not special type) with pneumatic actuation.
† Installed costs take account of accessories as well as installation.
‡ Figures are based generally on published data.

THE COST OF INSTRUMENTATION AND CONTROL INSTALLATIONS WITH COSTS OF MAINTENANCE

Tables accompanying Dr. Gillings' paper are shown alongside. Concerning these figures, Dr. Gillings commented that measurement of physical variables involves costs of the order of hundreds of pounds, but for analytical instruments they are around thousands of pounds. The costs of maintenance shown are average costs for a whole system. The figures involve no estimates of the economics of using instruments. The amount known concerning the effects of instruments on chemical plant on line is surprisingly small. Data are available for financial savings, but we are a long way from data giving the overall effect on process operation.

TABLE 1 (b)—Some Probable Ranges of Costs, Including Installation‡

Type of Unit	*Probable Installed Cost Range*
	£
Flow recording controller system*	400–500
Flow switch	50– 80
Level indicator†	100–200
Level recorder†	150–250
Level recording controller system*	400–500
*p*H indicator†	350–450
*p*H recording controller system*	500–700
Pressure controller	50–200
Pressure indicator	10 upwards
Pressure recording controller, system*	400–500
Speed indicator†	50–150
Temperature recording controller, system*	500–600

TABLE 2—Instrumentation Costs for Typical Plants

Type of Process	*Capital Cost* (£)		*Instrument Cost as % of Plant Cost*	
	Plant (1)	*Instruments (installed)* (2)	*Purchase and Installation Cost* (3)	*Purchase and Installation and Design Cost* (4)
Continuous multi-stage	11,000,000 4,200,000	650,000 250,000	6 6	7.5 7.5
Small continuous	920,000 160,000 120,000	71,000 11,000 12,000	7.6 7.0 10.0	9.0 8.5 12.0
Large batch multi-stage	7,500,000	330,000	6.6	8.0
Batch and batch/continuous	750,000 480,000 190,000	75,000 23,000 16,000	10.0 4.8 8.5	12.0 6.0 10.0

TABLE 3—Maintenance Costs by Instrument Type

Instrument	*Number in Service*	*Total Annual Charge*	*Type Average Charge*
		£	£
Flow indicator	118	1,534	13
Flow recorder	1,012	14,128	14
Flow recorder with pneumatic transmission	68	1,224	18
Flow recorder with electric transmission	70	1,200	17
Positive-displacement meter	630	8,190	13
Flow recorder controller	323	6,460	20
Flow recorder controller with pneumatic transmission	220	5,280	24
Flow recorder controller with pneumatic transmission and automatic index reset	33	924	28
Flow recorder controller with electric transmission and pneumatic control	62	1,450	23

TABLE 4—Maintenance Cost for Complete Installations

Works	*Value of Instrumentation* (£1000)	*Number of Maintenance Personnel**	*Value of Instrumentation Maintained per Man* (£)
A	107	13	8,600
B	207	18	11,000
C	257	23	11,900
D	26	2–3	10,400
E	94	16	5,800
F	126	13	9,500
G	94	14	8,600
H	138	12	11,200
I	29	4	7,300
Total for Nine Works	1,078	116	Average 9,300

* Numbers of personnel given as whole number nearest to average.

TABLE 5—Instruments and Components

Types	*Numbers in Service on Examples of Plant*		
	Single Distillation Unit		*Multi-stage Plant*
	Scheme A	Scheme B	
Indicators			
Pressure	—	—	650
Temperature	—	—	800
Level	(2)*	(2)*[A]	250
Flow	—	—	200
Recorders			
Pressure	(1)*	(1)	75
Temperature	(2)*	—	250
Level	—	—	2
Flow	(2)*	—	100
Controllers			
Pressure	(1)†	1[B] + (1)†	125
Temperature	(2)†	(2)†	175
Level	(2)‡	(2)‡[A]	75
Flow	(2)†	2[C]	100
Transmitter: Flow	—	1	

* Indicator, or recorder combined with controller. † Controller combined with recorder. ‡ Controller combined with indicator. *A* One level indicator controller is averaging type. *B* Pressure control set by temperature recorder controller. *C* One flow control set by averaging level indicator controller.

Enrichment in Partial Condensers

PARTIAL condensers are used for the incomplete condensation of mixed vapours with simultaneous enrichment of the uncondensed vapours. In total condensers the condensate has the same composition as the vapours, but in partial condensation the vapours are always richer in the more volatile component. If the condensate is in contact with the residual vapour, which is the case in condensation upon horizontal tubes, the greatest degree of enrichment of the vapour is the composition of vapour in equilibrium with the condensate. A much higher degree of enrichment is possible when the flow of condensate and vapour are counter-current to each other.

So far, neither a reliable method for estimating the surface requirements of partial condensers has been presented nor is it clear what limits of enrichment can be expected from this kind of condensation. Sometimes the mechanism of differential condensation is assumed to give the upper limit of enrichment in partial condensers. But VANECEK and STANDART[1] have shown recently, by means of experiments upon three dimensionally-different condensers, that this is not the case. They suggest that the greatest enrichment occurs in a countercurrent partial condenser when there is perfect radial and no axial mass transfer. In this case

$$y = \frac{R\,x^* + y_2}{R + 1} \qquad \ldots . (1)$$

where y = vapour composition;
x^* = equilibrium composition of liquid given by equilibrium relation $x^* = f(y)$;
y_2 = composition of vapour leaving condenser or a section of it; and
R = internal reflux ratio.

From a knowledge of the amount condensed and by means of the equilibrium relationship the upper limit for vapour leaving the condenser is given by

$$y_2 = y\ (R_e + 1) - R_e\ x_1 \qquad \ldots . (2)$$

where R_e = external reflux ratios = L_1/V_2
y_1 = composition of entering vapour;
x_1 = composition of liquid leaving condenser;
L_1 = condensate flow rate at lowermost end of condenser; and
V_2 = flow rate of vapour leaving condenser.

The results of more than 120 experimental runs[2] showed that the proposed limit of enrichment as defined by Equation (2) was in no case exceeded, although it was closely approached in a number of cases. The degree of enrichment was, however, influenced by a number of variables. Increase in the vapour-flow rate, for example, led to higher enrichments, while an increase in tube length tended to reduce enrichment and *vice versa*.

The authors found during their work that the NUSSELT expression for the condensing-film coefficient could be used for estimating the mean heat-transfer coefficient in their condensers, provided the boiling point of the mixture is used for determining the surface temperature of the liquid-film.

The experimental work shows that the enrichment which occurs in a countercurrent partial condenser depends to a great extent upon the operating conditions. Moreover, the degree of enrichment that can be attained cannot be explained by assuming that either the mechanism of differential or equilibrium condensation prevails in condensers of this kind. The enrichment obtained in practice occurs through evaporation of part of the condensate in the condenser with the result that some rectification takes place within it.

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A large settling tank at the Steetley Co.'s magnesia-from-sea-water plant showing wind shield for prevention of surface agitation.

MAGNESIA FROM SEA WATER

Advances in processing methods and expanding scale of manufacture improve the economy of a well-established process

PLANTS for extracting magnesia from sea water have been in successful operation in America, Britain and Norway and, depending upon the final kiln treatment of the magnesia, provide a material from which magnesium metal can be produced or which is suitable for refractories. In Europe, magnesium metal is produced via sea-water magnesia at the Norske Hydro Heroya plant, Norway, and refractory-grade magnesia on a large scale is produced at the Steetley Co.'s Hartlepool plant. There are also a number of other applications for sea-water magnesia, e.g., for paint fillers, medicines and thermal insulating materials.

There are two methods of precipitating the magnesia from the sea water. One method is to add lime to it, when the following reactions take place:

$$MgCl_2 + Ca(OH)_2 = Mg(OH)_2 + CaCl_2$$

$$MgSO_4 + Ca(OH)_2 + 2H_2O = Mg(OH)_2 + CaSO_4\,2H_2O$$

The other is to add burnt dolomite slaked (dolime) to sea water so that magnesia is precipitated according to the following reactions:

$$2Ca(OH)_2 + 2Mg(OH)_2 + MgCl_2 + MgSO_4 + 2H_2O = 4Mg(OH)_2 + CaCl_2 + CaSO_4\,2H_2O.$$

The main advantage of this process is the smaller plant it requires. Normally sea water contains aout 2.2 g/l of MgO present as sulphate and chloride. With lime as the precipitant, for 1 ton of MgO at a 70% yield, about 130,000 gal. of sea water are required. If dolomite is used, only about half of this gallonage is needed. Hence the sea-water processing parts of such a plant are much smaller, and much less power has to be spent in pumping sea water.

A serious competitor to the dolime sea-water process is the process based upon the calcination of magnesite which is extensively practised in Austria. Nevertheless, the Steetley Co. is able at its Hartlepool works to produce magnesia which can be sold at 70% of the price of imported magnesia derived from magnesite. This is a remarkable achievement, and it has made possible an annual saving of £4 million of foreign exchange and the export of nearly £1 million worth of magnesite and chrome-magnesite bricks. In addition, the sea-water product is superior to natural magnesite, since its composition can be adjusted to meet the requirements of the user. The combined effects of a very large scale of operations and a host of detailed technical improvements have made this achievement possible.

The Hartlepool plant is close to the dolomite deposits at Thrislington and Coxhoe, where the material is burnt to dolime and transported the short distance to Hartlepool in hopper-bottomed rail wagons. This procedure is appreciably cheaper than burning the dolomite at Hartlepool, since it avoids the cost of transporting the CO_2 content of the dolomite. The equipment for this early stage of the process includes, at Thrislington, one 350-ft-long rotary kiln equipped with a rotary cooler; steel heat exchangers operate in the feed end of the kiln and cooler. At Coxhoe there is one 300-ft-long rotary kiln equipped with planetary cooler, and five 100-ft-high shaft kilns fired with coke and fitted with skip-hoist feeds and automatic discharge mechanisms. At Hartlepool the pulverised dolime is first air-classified to separate the coarse material and then slaked before making into the slurry, which is fed to the parts of the plant in which the sea water is treated. There is also an alternative system of preliminary treatment included in the slaking section of the plant which makes use of a hydrocyclone for separating oversize material. This passes to a wet-ball mill and, when ground to the required size, is returned to the main supply of slurry. The available plant at this stage of the process comprises five hydrator units with self-regenerative heating systems all fitted with automatic weight-feeders, and two of the units rely upon the pneumatic system of classification and three upon the hydraulic system.

Compared with conveying as a solid to the points of use, transport of the dolime in slurry form has many advantages. The pipelines, however, have been designed to give ready access to points where blockages might possibly occur. Pumping is by open impeller centrifugals fitted with phosphor-bronze impellers and casings. Leakage from the shafts is prevented by mechanical seals. In the early days, however, when packed glands were fitted, leakage was considerable.

The sea water is drawn through five 950-ft-long cast-iron pipelines by centrifugal pumps and fed in to four concrete storage tanks of varying designs. These tanks, with a total capacity of 8 million gal., are enough to provide the plant with a continuous supply of water whatever the tidal conditions may be.

The sea-water pumps are capable of operating with a suction lift of 25 ft of sea water. Variation of the sea level —excepting low-tide conditions—does not affect the delivery of the pumps very much, since they have a very flat delivery-head characteristic. The flow to the storage tanks is controlled by hydraulically-operated butterfly valves. In common with other heavy consumers of power at the plant, the pump motors are fed by a 2750-volt, 3-phase supply. This is another measure contributory to the general economy of the process, since it demands smaller motors than those used with the more usual 400-450-volt supply. The motor hp—600 each—gives some idea of the magnitude of the power requirements of the present installation.

An interesting feature of the pump installation is the method of priming. A conventional method is to fit a foot valve which closes when the pump is shut down, so leaving a column of liquid for priming in the pipework system. This was tried in the early days of the plant, but debris fouled the valve and prevented it from closing. Frequent maintenance of the valves proved to be uneconomical and they were removed. The pumps are now primed by exhausting the lines by means of rotary vacuum pumps, each driven by a 25-hp motor, an arrangement which, despite the added expense of the vacuum pumps, has proved much more economical and reliable than the former one.

The possibility of extending the sea-water lines farther out to sea has been considered, but so far the disadvantages of carrying out maintenance work upon a submerged line has outweighed their possible advantages. At present, since the inlets to the pipes are uncovered at low tides, maintenance and inspection are not difficult. A future modification may be the lowering of the pumps to a position 5 ft below sea-level, a step which will reduce the cost of pumping, since the pumps will be smaller and require less priming. The quantity of water handled daily by these pumps —30 million gal.—emphasises the importance of improvements of this kind.

The sea water before passing to the tanks is passed through a sand filter, whence it flows via a peripheral launder to the storage tanks. The sand filter, like the storage tanks, is of concrete construction.

Sea-water Tanks

The capacity of the sea-water storage tanks is 8 million gal. and they represent a considerable investment. The latest type of tank, of which there are two, is made of cylindrically-cast reinforced-concrete rings without vertical joints. A P.V.C. water-bar is employed and the floor is asphalted, but otherwise the tanks are untreated internally. The remaining two tanks are of concrete construction; these have the vertical prestressing wires put in tension before erection. The vertical members are then assembled, jointed and the circumferential rings fitted and tension applied. Originally, the rings were covered with gunnite, which concealed them, but they now have bitumen coating. There have been failures of the cylindrical wires through corrosion which was hidden by the gunnite covering; vertical joint leaks which occurred were inexplicable until the gunnite covering was removed to reveal the fractures. Tanks of this type have shown a tendency to develop leaks at the base joints also. The more recently installed tanks have proved to be the cheaper of the two types, despite their greater first cost.

The first stage of chemical treatment is to remove the calcium bicarbonate of the sea water, as failure to do this would affect the purity of the finished magnesia. The refractories industry requires a low calcium content in the finished magnesia; hence this step is important, since it prevents the precipitation of calcium when the dolime is added at the reaction stage proper. A small quantity of dolime slurry is fed to the sea water contained in the five pre-treatment tanks. These are rake classifiers of 100 ft diameter with the feed through hollow agitation blades, the agitators being driven at 1 rph by 7½-hp variable-speed motors.

A bed of dense suspension with an approximate depth of 7 ft is maintained in order to allow the bicarbonate-to-carbonate reaction to be completed. An important feature of this part of the process is the addition of 1% poly-

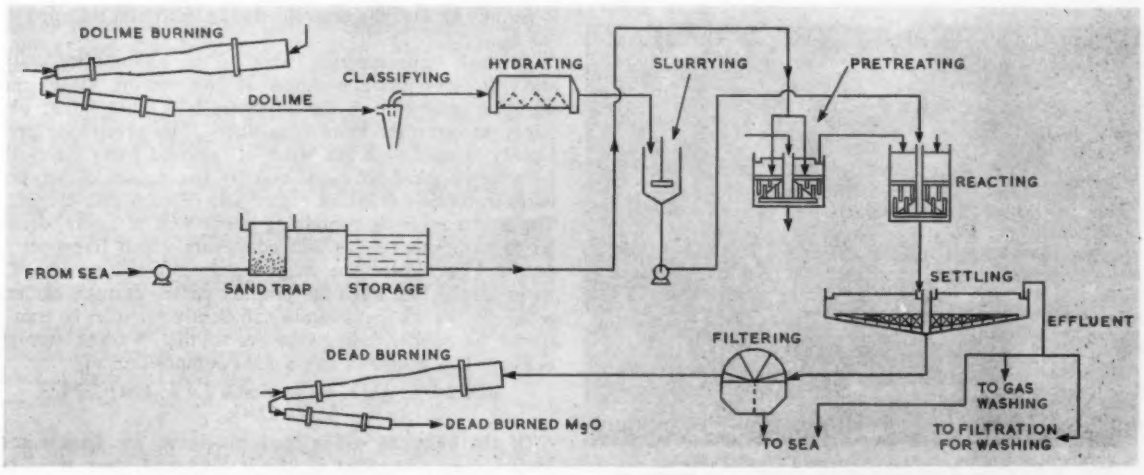

Fig. 1. Simplified flow diagram of the Steetley Co.'s Hartlepool magnesia-from-sea-water process.

electrolyte, costing 10s. a pound of pure material, to improve the settling properties of the precipitate. This solution is added at the rate of 7 gph for every 6000 gpm of sea water treated. So effective is the pre-treatment process that the sea water overflowing into the peripheral launder contains no more than 10 ppm of suspended solid matter.

The reaction and settling system comprises three groups of plant consisting each of two reactors and a settling tank of about 3½ million gal. capacity. The pre-treated sea water passes to cylindrical concrete reactor tanks fitted with agitators constructed from mild-steel angle; these have a number of vertical blades which pass between vertical stationary blades fixed at the base of each reactor. The edge formed by the angle of the section is also the leading edge of the blade when it rotates. Rotational speed is 6 rpm and the power is provided by a 75-hp motor; originally the power to the agitators was transmitted through a crown-wheel and pinion drive and one of these units is still in operation. The two remaining reactors are now fed with worm-gear units specially designed by David Brown, and are something of a novelty, since gears of this type have seldom been employed in the past for transmitting such high hps. The units operate quietly and with a minimum of vibration, in contrast to the older unit which is a great deal more noisy and causes appreciable vibration of the structure supporting the gears and motor.

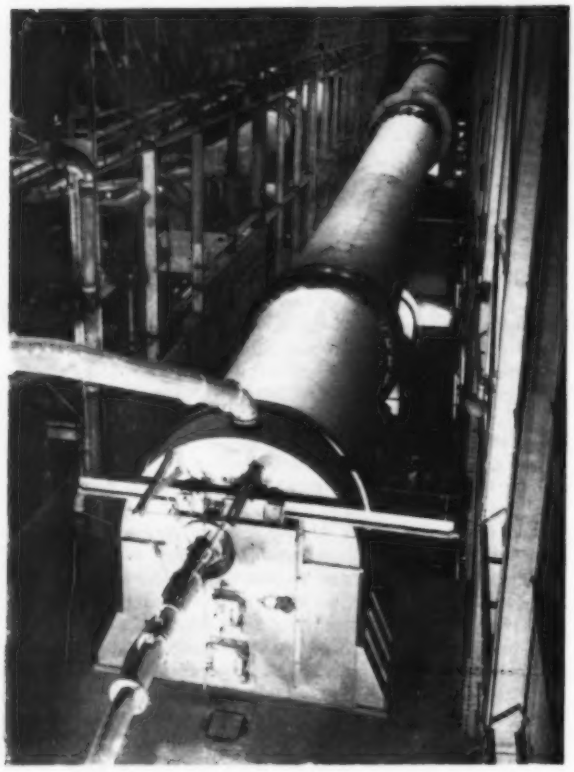

Fig. 2. One of the five rotary kilns in which the final product—Britmag granules—is produced. The kilns are fired by pulverised coal and operate at over 1600°C.

Fig. 3. Dolime hydration plant where the dolime is slaked with fresh water to a fine dry powder.

At one time it used to be necessary to heat the treated sea water to 90°C—a measure which consumed a considerable amount of heat. This expense is now no longer incurred, since the requisite properties of the precipitated magnesia has been obtained by other methods, including the treatment of the precipitated magnesia with unpolymerised acrylamide.

The reaction products pass via discharge connections at the base of each reactor to diaphragm pumps which transfer the slurry to settling tanks or lagoons. One of these is as much as 255 ft in diameter and is the largest of its kind in Europe. As in the pre-treatment tanks, the dense slurry is coaxed to the centre of the tank by a rake-cantilever type of stirrer which rotates at 1 rph, power being provided by a variable-speed 7½-h.p. motor-gear unit.

At one time surface disturbance caused by winds used to interfere with the settling process, but this problem has now been solved by fitting a wind shield around each tank. This stage of the proces requires control of *p*H to a value in the vicinity of 11. Attempts to control *p*H automatically have been unsuccessful, because, so far, no really reliable electrode has been found and the variable is therefore controlled through periodic manual titrations.

The magnesia slurry is transferred to the washing tanks by diaphragm pumps and after washing with sea water is transferred to a battery of 11 vacuum ten-disc filters fitted with variable-speed drive. Effluent from the washing and settling processes is returned to the sea, although some is routed first to the kiln gas-washing plant. The heavy-gauge, nylon-fabric-filter medium is fitted over discs assembled from a number of grooved sycamore sections attached to cast-iron connectors. Through these, the filtrate is withdrawn into the central rotating shaft and returned to the sea.

Through improvements, such as the nylon filter cloth and the acrylamide addition at the settling stage, the filtration output from the 11 filters is 3.7 times that obtained at one time from nine filters. The precipitate previously washed with sea water is removed from the cloth by a compressed-air blow and by the action of scraper wires in tension fitted on either side of each disc element. The separated cake, containing about 50% moisture, drops on to troughed rubber belt conveyors which transport it to the kilns where the magnesia is calcined to 1600°C. After leaving the kilns the product passes through coolers which reduce its temperature sufficiently for it to be transferred by rubber belt conveyors to the 7500-ton storage bunker. The magnesia has a final composition of:

SiO_2 2.1%, Al_2O_3 1.4%, Fe_2O_3 1.4%, CaO 2.7%, MgO 92.4%.

Of the kilns, of which there are three, the largest and most recently installed is 250 ft long and, over most of its length, has a diameter of 9 ft 10 in., while the feed

section of this kiln measures 11 ft 10 in. in diameter.

The time of passing through the kiln is 6 to 8 hours and the shell rotates at 1 rpm. The kiln conditions of temperature and retention time are closely controlled; the rotational speed, for example, is controlled by means of a Ward Leonard set. On the kiln instrument panel there is also a tachometer graduated from 0-1.25 in 100ths of a rpm.

Each kiln is fired by pulverised coal from a two-compartment ball-mill; unlike many other pulverised coal-firing systems, the fuel is stored first in a hopper instead of being fed direct to the burners. Small worm conveyors eject the fuel into the air stream conveying the fuel to the burner. This is a flexible system which provides a very steady feed of coal. The air supply to the burner consists of air conveying the fuel and the secondary air which is supplied separately. In addition, a tertiary air supply from the coolers is fed into the combustion space.

The fuel burner barrels are made from a high chromium austenitic steel alloy and they are not water cooled, as this step is considered wasteful of heat. Although the barrels are expendable—the average life is about two years—they are more economical than water-cooled barrels.

In order to reduce the emission of solid matter to the atmosphere to a negligible level, the kiln gases, containing water vapour, volatilised salt and magnesia dust, are treated in a plant which cost approximately £300,000 in its final form. The gases are first washed in three hexagonal 70-ft-high, 10-ft-wide concrete towers which operate in parallel. Each tower is packed in its upper half with criss-cross slats, over which sea water is distributed. A number of jets of effluent water below the packing cool the gases before they reach the packed section. This process is not enough, however, to remove all the entrained solids from the gases, and electrostatic precipitators operating at a voltage of 50,000 are employed to remove the very fine particles from the gases. These have proved very effective and an efficiency of 99.5% removal of solids has been achieved.

The washing towers are Nori brick-lined with cashew-nut cement used for the joints, which are kept as small as ¼ in. The trunking conveying the partially cleaned gases to the electrostatic precipitators is part P.V.C.—and part rubber—lined, and the exhaust fans a'so are rubber covered.

When first installed, the precipitators did not perform as expected; electrode vibration was suspected, although strong doubts were expressed about such a possibility. These doubts were removed when a small inspection hole, protected by an expanded metal sheet, was made in the precipitator body and vibration in the rods was in fact observed. The electrode assembly was subsequently made more rigid by placing the rods under tension, and as a result, the precipitators operated successfully. But corrosion of electrodes is at present severe, and their life is little more than six months. Experiments are now being carried out with titanium electrodes, and early results show that replacement of the present sulphuric-acid plant type by electrodes of this material may solve this problem.

To appreciate fully the achievement the Steetley Co.'s Hartlepool plant represents, with its £5 million investment and capacity of 150,000 tons per year, it is necessary to recall that the basic process was worked out in a pilot plant which can still be seen to this day. It consists of a small gas-fired kiln of 13 ft x 15 in. diameter, a small centrifugal pump, an ordinary household bath and a bucket and pole.

Supply and Distribution of Chemical Engineers in Great Britain

ACCORDING to an analysis of its membership published by the Institution of Chemical Engineers, the supply and demand position in chemical engineering is still far from satisfactory. In estimates of future trends in manufacture and trading, the difficulty of including the chemical engineering manpower factor arises partly from lack of statistical information. The Report on Scientific and Engineering Manpower in Great Britain[1] (H.M.S.O., 1956) gave the total number of qualified chemical engineers in Great Britain in 1956 as 1500, and the total number required by 1959 as 2200—qualified chemical engineers being defined as persons holding university degrees or associateships of certain colleges in the subject and Corporate and Graduate Members of the Institution. These figures were obtained by using a sampling procedure. An examination of the figures published in the Appendices to the Report indicates that 59% of the total number of chemical engineers are employed in three main branches of industry—namely, the Chemical and Allied Trades (590), Mineral Oil Refining (142), and other Plant and Machinery (155).

It has been estimated on behalf of the Institution that the total population of qualified chemical engineers in Britain in 1956 should have been of the order of 5000 and that the population should increase to 10,000-11,000 by 1966. The recent survey of output per annum of qualified chemical engineers from universities and technical colleges in Great Britain[2] gave the following figures:

1956	1966 (estimates)
277	940

If an output of 900 is realised in 1966 the needs of expansion and replacement may be met, though it is unlikely that the present shortage of qualified men will be made good by that time. The 1956 apparent shortage, that is the difference between 1500 and approximately 5000, does not mean, of course, that there are, or were, 3500 vacant chemical engineering posts in industry.

If there is a serious shortage of chemical engineers, then it is important to know which industries are most affected. In the analysis made by the Institution the Standard Industrial Classification is used.[3]

Analysis by Occupation

There appears to have been some increase in the proportion of members employed in administration (1953 = 20%; 1957 = 30%), together with a decline in the proportion engaged in plant operation (1953 = 23%; 1957 = 12%). Compared with the latest known figures for the U.S.A., the percentage employed on research and development is low (Great Britain = 23%; U.S.A. = 31%), while those employed on design, construction, installation and commissioning is high (Great Britain = 21%; U.S.A. = 7%).

Analysis by Industry

It is found from this analysis that the greatest concentration is in the mineral oil refining industry followed by the chemical and allied trades. Moreover, as far as these industries are concerned, the greater the concentration of scientists and engineers, the greater the concentration of chemical engineers.

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AMERICAN LETTER

Fume and Dust Control Developments

IT should not be inferred that because of a vast geographical area America is largely free from industrial air pollution. Indeed, the smogs of Pittsburgh and Los Angeles were notorious until steps were taken to lessen these nuisances—with remarkable success as far as Pittsburgh was concerned. Surprisingly, however, serious atmospheric pollution problems can also arise from industrial plants located far out on the prairie or plain. The trouble may be due to fume alone or may be caused by dust—but not infrequently both factors are involved. Some of the more common pollutants from American industrial plants have ranged from harmful toxic gases, corrosive vapours and alkali spray, to unpleasant dusts from cement works, mineral recovery plants and power stations. Occasionally, the pollution may be merely a bad smell with a high nuisance value, but virtually harmless.

Air pollution can also be a hazard to vegetation and livestock as well as humans, even in low and apparently safe concentrations, since the effect may be cumulative. A major problem of this nature was recently solved at an investment cost of some $9 million, after about half of this figure had been previously paid to ranchers in the form of compensation. This arose at the Geneva plant of U.S. Steel in Utah and was caused by the presence of fluorine in the gases from sinter beds and open-hearth furnaces. Initial attempts at wet-scrubbing had been abortive, owing to rapid corrosion by the resulting HF solutions. After nearly a decade of development work, a system was installed which is based upon the unusual method of directly injecting calcium-hydroxide dust into the hot-gas mains prior to cycloning, followed by a further injection of ground limestone dust, further cycloning and dry precipitation. The resulting calcium fluoride is largely removed by the cyclones, and an electrostatic precipitator (said to be the largest in the world) completes the dust recovery. Fluorine removal from the gas is said to be 96% efficient. Two important maxims have been observed at this plant. The first, recognising that prevention is better than a cure, ensures that about 50% of the fluorine present in the furnace charges is fixed and removed in advance via the slag by the addition of lime. The second utilises the possible benefits of a phase change, so that an easily-handled solid is produced and removed instead of a difficult gas or liquid.

The effects of suspected fluorine pollution upon vegetation (and hence cattle) is also being studied in central Florida, where numerous phosphate rock treatment plants and fertiliser concerns are located. A wide variety of gas and dust scrubbing equipment is found in this region, ranging from simple wash-towers and bag-houses to the latest impingement separators and precipitators. The total fluorine lost to the atmosphere is believed not to be great. Nevertheless, the cumulative effect upon cattle cannot be ignored, especially since more industrial plants have recently come on stream. A complicating factor in this area is introduced by the simultaneous manufacture of sulphuric acid, aggregating thousands of tons daily, which must, in turn, give rise to a considerable emission of sulphur-containing gases to the humid atmosphere of this region.

See "Control of Fluoride Air Pollutants", British Chemical Engineering, November issue, p. 623.

Equipment Available

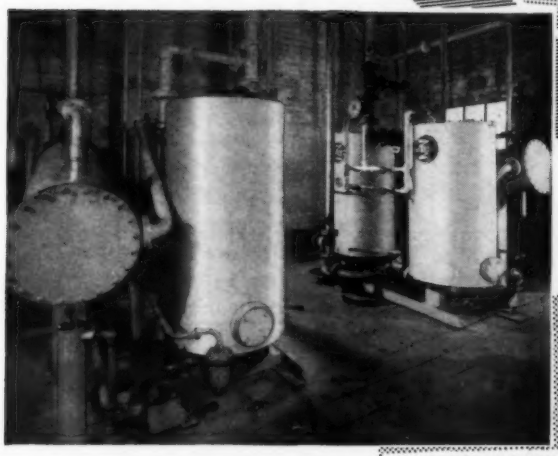
As regards equipment, an almost bewildering number of dust collectors, air filters and fume scrubbers has appeared on the American market in recent years. Few radically new principles have been developed, but numerous designs to reduce running costs, attention and maintenance have been introduced. At the same time, separation efficiencies have improved, except in some stubborn applications such as certain acid mists. Odour control by absorption, oxidation or reaction has also been effected at some plants. The simplest form of solid/gas separator, the cyclone, is generally available with efficiencies of 98 to 99% down to 20 microns, while multi-unit small-diameter assemblies are obtainable for separations down to about 5 microns. Some makers, such as Ducon, install internal scrolls, apex shields, etc., while other manufacturers rely on close design tolerances to achieve maximum results. One company, the Dustex Corporation, markets an interesting high-efficiency collector incorporating cast tubes only 18 in. high. When a wet product is permissible, some concerns use wetted walls or sprays to increase recoveries. In a few units, the collector tube or cyclone is mounted horizontally and precipitation is encouraged by vanes, scrolls, sprays and wetted walls. The Jeffrey "Microdyne" collector is of this type and can be mounted in-line with the associated ducting, a useful advantage in confined spaces. Pressure drops of only a few inches and recoveries down to below 5 microns are claimed for the Jeffrey collector.

Recent designs of bag filters display considerable ingenuity in the operation of self-cleaning and discharge mechanisms. The Mikro "Pulsaire", for instance, incorporates an internal air blast which periodically distends each bag slightly to shake off the accumulated dust, while the Sly "Roll-Clean" Dynaclone employs a travelling air-purge mechanism which slowly traverses the open end of each bag in turn and this cleans by inducing a reverse air-flow. Sealing is obtained by large sponge-rubber rollers.

There is no doubt that post-war developments in the design of impingement-type separators and scrubbers have greatly assisted air pollution problems, in addition to raising plant recoveries. Such scrubbers, while removing soluble impurities and solid particles (often in the sub-micron range), use very little liquid and offer a reasonable pressure drop. For example, the ARCO jet scrubber requires 5 to 10 gal. per 1000 cu. ft of gas and has a pressure drop of 1½ to 4 in. w.g. for recoveries of 97% or so, down to 1 micron. The ARCO jet impactor and the Chemico Pease-Anthony scrubber will remove sub-micron particles and mists, with similar liquor consumptions, at pressure drops of 10 to 20 in. The recently marketed Doyle impingement scrubber uses only 1 to 2 gal. per 1000 cu. ft of gas and will remove soluble impurities, as well as many materials in the sub-micron range. Removal efficiencies of 98 to 99.5% have been cited. Finally, the dust and fume control service offered by the Johnson-Marsh Co. is worthy of mention, since it aims at the prior prevention of air pollution by spraying surface-active solutions at strategic points in an operation, e.g., conveyor take-offs, milling stations, ore bins, etc. There is no doubt that the principle of prevention could be used in many cases to a much greater degree, with consequent benefits to industry and the community in many parts of the world.

BCE 4254 for further information

Drying Hydrogen for Carbide Tools



In the manufacture of Prolite tungsten-carbide tools, Murex Limited use Birlec adsorption dryers to remove water vapour from their electrolytic hydrogen supply.
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Illustration above:—
Birlec adsorbers for hydrogen drying.
Illustration right:—
Electrolytic hydrogen plant at Murex Limited.

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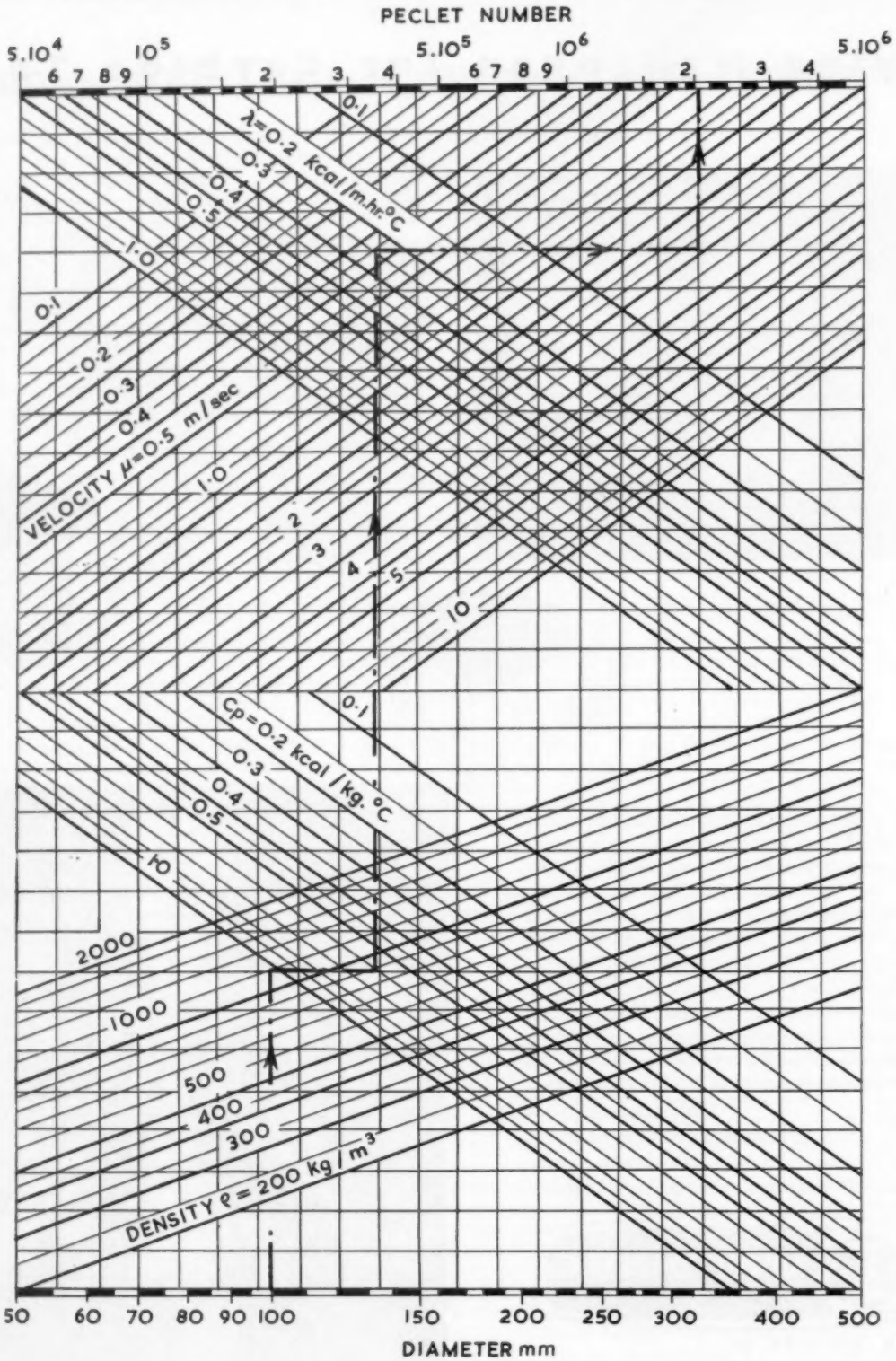

British Chemical Engineering
NOMOGRAM NO. 31

BCE 4255 for further information

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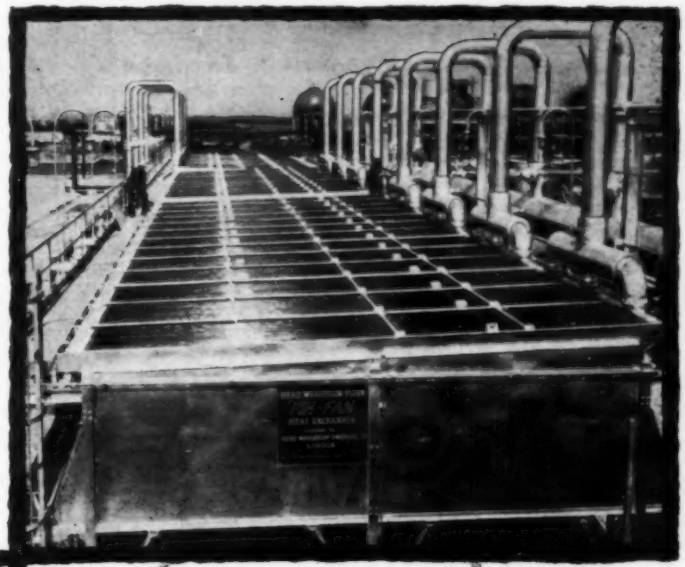

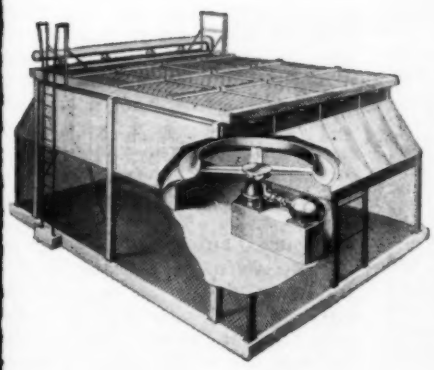

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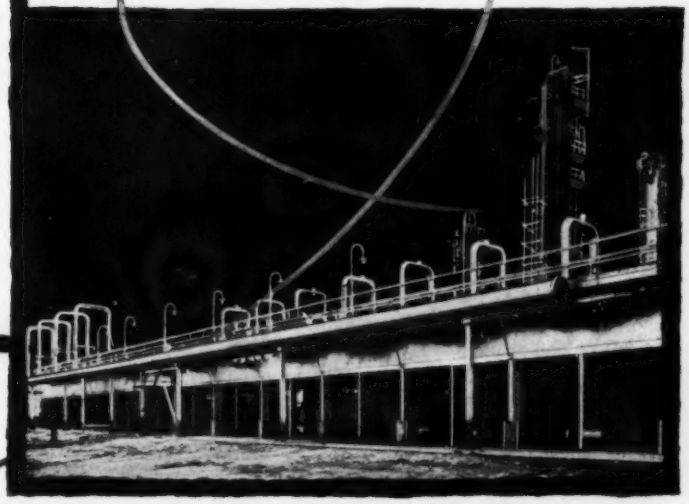

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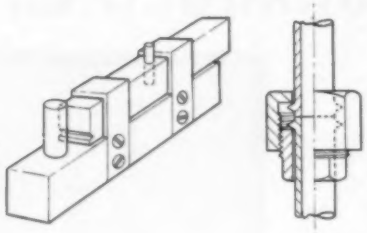
P.5287

PROCESS ENGINEER'S NOTEBOOK

A Simple Jig for Instrument Line Fitting

THE VARIOUS TYPES of instrument pipe fittings which are used generally on copper gas lines depend on contact between a second element, such as an olive, collet or cone, to secure the end of the pipe and enable a screwed joint to be made. In practice, this attachment can seldom be broken and remade, because of damage to either the attachment or the end of the pipe. To eliminate the need for this secondary element and to use an attachment which is an integral part of the pipe, the simple jig shown in the accompanying sketch was devised.

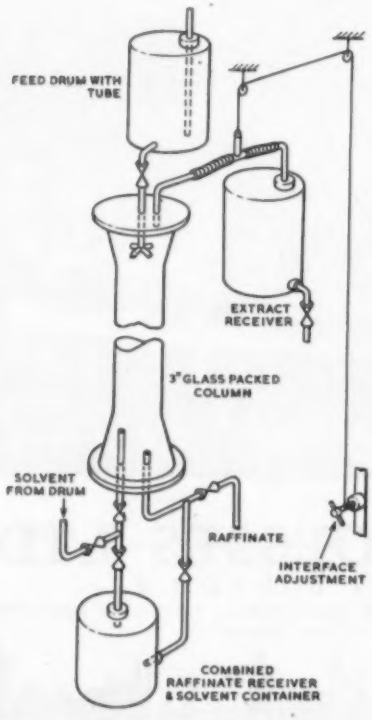


This can be held in an instrument mechanic's vice and, with the pipe end over the spigot, a few sharp taps on the anvil will form a secure attachment on the end of the pipe. This operation can be performed satisfactorily in the limited space available behind the instrument panel and the resulting joint has never been known to fail.

F. MOLYNEUX

Liquid-Liquid Extraction Plant

A PILOT PLANT liquid-liquid extraction apparatus for extracting a dilute aqueous solution of an organic compound with a solvent such at toluene is shown in the accompanying diagram. At first an attempt was made to pump the solvent up the column and to control the flow by throttling, but frequent adjustments were required and, in addition, control of the interface level proved difficult. The solution to be extracted was fed by gravity from a 10-gal. drum; changes in head also caused variations in flow of feed to the column and, therefore, a number of improvements had to be made to the apparatus. In its final form the drum was modified by sealing and fitting an air bleed to give a constant head (Mariotte principle). Solvent was likewise fed by gravity to a batch container at the base of the column. The connections of the container were arranged so that the aqueous raffinate was discharged from the column into the receiver. As a result, toluene is displaced upwards into the column continuously and out of its top into the extract receiver. When the entire batch has been discharged the process is stopped. It is convenient to make the volume of the feed somewhat less than that of the solvent. The column itself was a standard 3-in. glass pipe packed with ¼-inch glass beads. One shortcoming of this method is that the ratio of raffinate to solvent cannot be made different from unity. Nevertheless, it should be possible to divert either a proportion of the displaced solvent or the raffinate descending the column. The ratio of solvent to raffinate can be increased by fitting a separate feed of either aqueous solution or water to the base receiver and which by-passes the column. The quantity of raffinate which actually passes down the column can be found by the change in level in the feed tank. If the solvent is required in a lesser proportion a connection should be made from the base of the column into a separate measuring container. A proportion of the solvent can then be drawn off continuously instead of passing up the column.



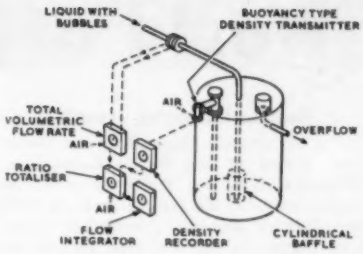
Sintered Metal Tank Vents

TO IMPROVE THE SAFETY conditions at a plant, a tank containing inflammable solvents had to be fitted with a vent which would discharge vapours upwards rather than downwards. The first vent used with the tank consisted of a sharp 180-degree return bend fitted to a short length of pipe attached to the tank. A gauze disc was fitted at the open end to act as a flame arrester.

The requirements of the new vent were that it should allow vapours to pass through without excessive resistance, that it should prevent ingress of dirt and water, be cheap, corrosion-resistant and maintenance free. It was also desirable that the replacement should act as a flame arrester. A number of vents were examined, including some made of porous ceramics and woven wire cloth. The ceramic type, while fulfilling most of the conditions, offered too much resistance to vapour flow when the tank was being filled. Those of the wire cloth type, on the other hand, did not last very long, although they satisfied the other requirements. The final satisfactory solution was a sintered-metal vent, paraboloid in shape, made from a copper-tin alloy. This was fitted on the original pipe connection once the original return bend was removed. The sintered article had a voidage of 40-50%, which was sufficient to prevent water finding its way into the tank and to give freedom of movement for the vapours. With a 2-in. diameter vent of this type the rise in pressure inside the tank is not greater than 1 in. water gauge when the solvent flow is about 80 gpm.

Measuring Gas-Liquid Flow

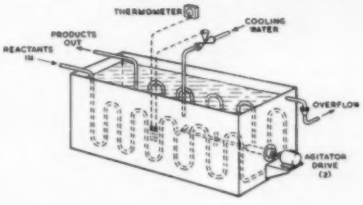
THE RATE OF FLOW of a liquid containing small bubbles of gas is not easily measured, particularly if the proportion of gas to liquid varies with time and if the volume of gas bubbles is greater than a few per cent. Measurement of volumetric flow will only be satisfactory if the amount of gas present is constant and the density of the mixture known. One answer to this problem is to use a volumetric flow measurement instrument in conjunction with a density-measuring instrument and to combine the two measurements to give a corrected value of either weight or volumetric rate of flow. A simple orifice-meter may be used followed by a buoyancy-type density meter fitted immediately downstream of the orifice to a constant-level tank of small volume. A ratio totalling instrument is fed with the output signals from these two instruments so that the product of the two readings gives the weight flow. The output from the multiplying instrument may be transmitted to an integrator for recording the total quantity of liquid delivered over a given period. The volumetric



rate of flow of liquid can be obtained from the readings by dividing by the liquid density. This method can be used safely for pressures up to about 3 to 4 atmospheres.

Self-operating Thermostatic Valve

AN INEXPENSIVE SELF-OPERATING thermostatic valve is used in this method of controlling the temperature of an exothermic organic chemical process. The reaction is carried out continuously in a pipeline reactor consisting of a twin-bank stainless-steel serpentine coil. This is fitted inside a water bath provided with two propeller-type agitators, one at each end to circulate the water vigorously and to prevent the occurrence of hot spots on the coil. The bulb of the valve is placed in the water bath and is also attached to the bulb of a temperature indicator or recorder. This gives a close check on the bath temperature and makes for accurate adjustment of the thermostatic valve. The alternative



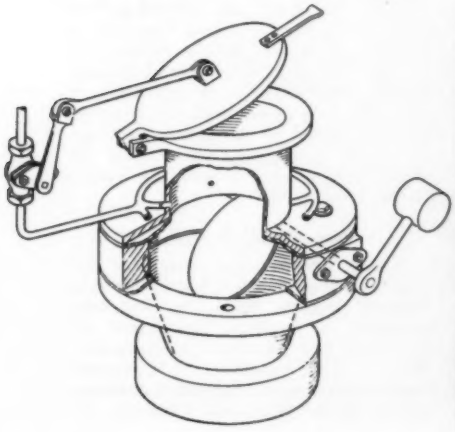
of placing the valve thermo-element in the reactor fluid stream is practicable, but is objectionable if the fluids are corrosive. The range of thermo valve required in this case may also be different from that normally obtained which may mean a more expensive valve. Operation is straightforward; a rising temperature of the cooling water beyond the set point causes the valve to open. A further supply of cooling water then flows into the bath and excess is displaced through the overflow connection on the tank.

Specially-designed Sodium Charging Head

IN THE PREPARATION of sodium methoxide by the addition of sodium to methanol in an atmosphere of nitrogen, it is essential for the sodium charge to be fed safely to the methanol without the introduction of moisture-bearing air. A sodium charging-head has been specially designed for the sodium methoxide reactor in the corticosterones plant at Boots' factory, Beeston, Nottingham, and it is shown in the diagram. To introduce sodium into the vessel, the upper cover is opened and the lower flap closed. By means of a stop-cock which is coupled to the spindle operating the hinged lid, nitrogen is fed into the head when the lid is open. The sodium is then placed on the lower flap and the lid closed. This closure automatically cuts off the nitrogen flow, and the sodium may then be discharged into the reactor by lowering the flap.

Other precautions taken in the preparation of sodium methoxide can be seen from the photograph. No electric cables enter the building containing the reactor and light is provided at night time by external lamps focused through glass - brick windows. Numerous fire-extinguishing points are fitted in the building and condensation is prevented by adequate space heating of the building.

(Courtesy of Boots Ltd., Beeston, Notts.)



Contributions invited

THE EDITOR invites readers to submit, for possible publication in "Process Engineer's Notebook", notes on practical devices that have been elaborated on the job for improving the operation or increasing the safety of processes, or that have been extemporised in special circumstances. The contributions preferably should be of about 250-500 words, and be illustrated with a line diagram or sketch, or a photograph. A minimum of three guineas will be paid for each contribution used. They will be published anonymously or under the contributor's name, according to his wishes.

World of Chemicals

Russian Industrial Growth

Figures recently released by the Statistical Board of the Soviet Council of Ministers show that the gross industrial output plan for the third quarter of 1958 was fulfilled by 102%, and that industrial output in the first nine months of the year increased by 10% over the corresponding period of 1957. The chemical and rubber industries increased production by 12%. Output of mineral fertilisers during the first nine months of 1958 grew by 0.6 million tons to 9.2 million; that of cement by 3.2 million tons to 24.4 million; and that of oil by 11.4 million tons to 83.4 million.

Russia will organise industrial, technological and scientific exhibitions in 16 countries in 1959, according to Mikhail Nesterov, president of the presideum of the Russian Chamber of Commerce. The Leipzig Fair and international fairs at Casablanca, Brno, Budapest and Damascus are among the exhibitions at which the displays will be shown. In addition, there is the national exhibition of the Soviet Union which is due to take place in New York in the summer of 1959.

Hygrotherm Engineering Ltd., London, were awarded a contract by V/O Technopromimport, Moscow, recently for an automatic heating and cooling plant to be used in the manufacture of synthetic resin. It will consist of heat generators, circulating pumps and control equipment. The heat-transfer medium will be the organo-silicate Hygrotherm TAS-190.

A technical achievement claimed for a team of Soviet physicists by the Soviet News Agency, Tass, recently is the attainment of a record pressure of 5 million atmospheres, "ten times greater than the previous world record held by U.S. scientists". (Prof. P. W. Bridgman of Harvard University had already obtained pressures of 400,000 atmospheres by 1952, when he outlined refined techniques that should be capable of attaining higher pressures.)

Gas Production and Distribution

Construction started on the Scottish Gas Board's Lurgi pressure-gasification plant at Westfield, Fife, recently, when Lord Mills, Minister of Power, inaugurated the operations. The plant is due to be in part operation by July, 1960, and to be completed by the end of 1962, when it will produce 30 million cu. ft of gas daily. The first section, 13 miles long of the 133 miles of high-pressure pipeline required for distributing the gas has now almost been completed by Constructors John Brown. The technique they are using is based on American methods for oil and natural-gas pipelines.

In Austria a natural-gas pipeline system, carried out on behalf of NIOGAS and involving the laying of about 130 miles of welded steel pipe, was completed recently, a month ahead of schedule, the contractors being C.J.B. in association with Williams Bros., of Tulsa, Oklahoma, and Engineer Hugo Durst, Austria.

The construction of the 2,294-mile Canadian natural-gas line—the longest in the world—was also completed recently, and it has been tested to the approval of the Board of Transport Commissioners. The Canadian Government is expected to authorise the export of natural gas to the U.S.A. and Trans-Canada Pipe Lines have applied already for permission to pipe gas across the U.S. border to the Tennessee Gas Transmission Co. T.G.S., in turn, are seeking from the U.S. Federal Power Commission a licence to import 204 million cu. ft of Canadian gas daily at Emerson, Manitoba.

Sasol Expansion

Sasol, South Africa's oil-from-coal plant (see BRITISH CHEMICAL ENGINEERING, 1957, May, June, July and August), has started a consolidation scheme which will cost about £4 million and take some two years to complete. The scheme embodies the erection of additional standby equipment, including boilers and synthesis reactors, to enable the plant to function continuously. The existing unit has to be closed down periodically for maintenance and inspection. The programme will not be financed by addition to the capital structure of the Corporporation but by taking funds from the sale of Sasol products and, if necessary, by short-term loans. It is expected that the new scheme will result in a 35% increase in production within a year of its completion.

Plastics Sales in Britain

In the second quarter of this year sales of plastics materials were 97,900 tons, or nearly 2% below the second quarter of 1957. The particularly fast growth in sales that occurred in the first three quarters of 1957 began to level off towards the end of last year; although sales have now fallen below those of a year ago, they are still above those of 1956. Because of the stock build-up of plastics materials in the second quarter of this year, the estimated rate of production remained high, and was about 4% above the level of a year earlier. Sales of thermosetting materials at 42,100 tons were 2% lower than a year earlier and the rate of production was also down to about the same amount; stocks at the end of the second quarter were the same as a year earlier. Sales of thermoplastic materials at 55,800 tons were about 1% less than a year earlier. Because of a stock build-up in the second quarter production was maintained at about the same high rate as in the previous six months, and well above that of a year earlier.

Cement Plant Using Furnace Slag

A new cement plant with a capacity of 35 tons an hour and said to be one of the largest on the Continent has been commissioned by Cement Factory Ijmuiden N.V., an organisation owned jointly by the Royal Dutch Blast Furnaces and Steelworks N.V., Ijmuiden. The plant uses slag from the blast furnaces as a raw material; it is the fifth now owned by the company, whose production it brings up to 600,000 tons annually.

French Industrial Expansion

The turnover of the French chemical industry in 1956 amounted to 920,000 million francs (£785 million) as compared with 819,000 million francs (£695 million) in 1955, an increase of 11%, according to a report just published by the Ministry of Industry and Commerce. Taking the year 1952 = 100 as the basis, the overall production index rose to 163. The increases in production were particularly marked in fertilisers, petrochemicals, plastics, chlorine, inorganic chemicals and organic chemicals. Total exports to foreign countries and to the French Union amounted to 114,000 million francs (£97 million), and the imports to 89,000 million francs (£76 million). There was an adverse trade balance with foreign countries.

German Paper Making

The 1957 turnover of Zellstofffabrik Waldhof, including that of the manufacturing companies in which it holds a controlling interest, exceeded DM 400 million (£34 million) for the first time since the formation of the company and is about 10% higher than that of the previous year. The rise results partly from an increase in production, particularly in paper converting, and partly to the acquisition of two new subsidiaries—Papierfabrik Fleischer G.m.b.H. at Eislingen/Fils, and a majority interest in Maytex-Werke G.m.b.H., Mayen/Eifel. A dividend of 6% is being paid for 1957 (4% 1956). Sales during the first half of 1957 were "satisfactory" but were affected during the second half of the year by the slackening of demand in many countries.

Quality Control in Europe

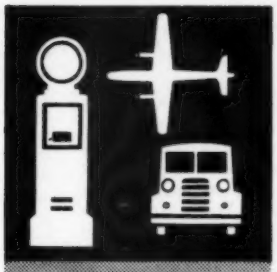
The British Productivity Council has been appointed to represent the United Kingdom on the European Organisation for Quality Control, Rotterdam, a body set up by the European Productivity Agency. To bring the advantages of membership of the organisation to as wide a section of British industry as possible, and to ensure continuing membership, the Council is instituting a subscriber service in which all organisations interested in quality control are invited to participate. Details can be obtained from the Council, 21 Tothill Street, London, S.W.1.

New Plants Overseas

A new phenol plant using the Distillers' process, and designed by Stone & Webster, Boston, Mass., has just been completed at Iwakuni City, Japan, for the Mitsui Petrochemical Co.—In Seattle, Wash., a 25% expansion of its vanillin production capacity has just been completed by the Monsanto Chemical Co.

BCE 4256 for further information

CATALYSTS



ALUMINIUM SULPHATE

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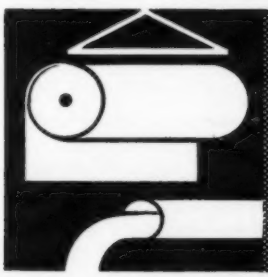

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Book Reviews

An Introduction to Automatic Computers

by Ned Chopin

D. van Nostrand, London, 1958, 525pp., 51s.

ON the dust-cover the title of this book is qualified by the sub-title "A Systems Approach for Business" and this makes it clear that the subject-matter is much less general than the title suggests. The scientist or engineer will not find here any adequate discussion of computers applied to his problems. Throughout, the emphasis is on business systems, their analysis and the application of computers to them. The first half of the book defines what is meant by a business system and studies various aspects of the use of computers in such systems—methods of input and output, costs, advantages to be gained, etc. The second half contains an elementary account of the components of a computer and the logical basis of their operation. A long appendix (75 pp.) gives comprehensive details of twenty American computers. The author has a down-to-earth approach and the book will be useful to those considering the use of a computer for data processing in business. Unfortunately, the virtues of the book are partly obscured by lack of conciseness in the writing.

H. H. ROSENBROCK

Particulate Clouds: Dusts, Smokes and Mists

by H. L. Green and W. R. Lane

E. & F. N. Spon Ltd., 1957, 425 pp., 70s.

THE chemical engineer is frequently concerned with the handling of particulate material in one form or another. The basic requirements of many unit operations are such that in order to achieve high efficiency in mass, momentum or heat transfer, it is often necessary to produce and disperse, in a controlled manner, solids and liquids in the form of small particles. Alternatively it may be necessary to design efficient collection systems which will trap such material either on account of its value or of its inherent nuisance. The properties of small particles are therefore of considerable interest to the chemical engineer, and this book, while not treating the topic primarily from this point of view, gives a much needed review of the basic physics of particulate clouds.

The first part of the book deals with the fundamental properties of dusts, smokes and mists and includes chapters on their production, dynamics, filtration, evaporation and methods of sampling, sizing and counting. The second part is of an applied nature and briefly describes those properties which are peculiar to certain fields, particularly collection, health hazards and atmospheric pollution.

The authors' prime aim has been to appraise only those references which they considered to contribute usefully to the subject. However this has resulted in a few shortcomings which may mislead the reader as to the present state of knowledge in certain fields. For example, the simple gas-blast atomiser, described in the first chapter, is the least efficient of its kind. For many applications, preferred designs are those in which the liquid jet is pre-filmed before it meets the gas blast. Similarly, in the same chapter, the four pages which are devoted to rotary atomisation might well have made reference to the spinning-bowl and vaned-disc atomiser which can handle larger flow rates more efficiently than the flat-disc atomiser. The applied sections are generally the least useful since they have been considerably condensed in order to keep the volume to a reasonable size. This was particularly noticed in the section on cyclone collection system and the chapter describing some common uses of particulate clouds.

These are but minor criticisms of a book which has collated information from a wide variety of topics, and will be a valuable source of information to newcomers and to all those at present engaged in this field.

N. DOMBROWSKI

A Textbook of Brewing—Part 2

by J. de Clerck, translated by Kathleen Barton-Wright

Chapman & Hall, London, 1958, 650 pp., illustrated, 105s.

BREWING is but one of the major industries based on microbiological processes. The art of the brewer, based on experience and judgment, has been increasingly supplemented in recent years by the application of scientific methods. It is no exaggeration to say that the high quality and uniformity of present-day beers is due in no small measure to this development, and in modern practice a knowledge of science is indispensable. The second volume of this excellent book is devoted to meeting this need. The first and major part is concerned with principles, while the second part shows how these principles may be applied to control of the various stages of beer manufacture.

Sufficient theory is given to provide a sound understanding of the significance of such things as *p*H, *r*H, colorimetry, photometry and other topics. At the same time the reader receives an adequate description of the working principles of the instruments employed, and the whole work is liberally sprinkled with information on the precautions needed when applying the method. Perhaps the only real disappointment in the early chapters comes from the sections on chromatography as applied to the analysis of sugars and hops. The impression created is that this technique is quite easily carried out by following a few simple instructions, or that it is not of sufficient importance to justify fuller treatment. One may search the index in vain for the word "chromatography". This seems to be inadequate recognition of a technique widely used in research, and by no means out of place in a routine laboratory.

In the chapter on microbiological control, the air sampler shown may be simple in construction and operation, but its efficiency and utility cannot be compared with that of the slit sampler which receives no mention. Not only is the latter device almost the only means of trapping and identifying single cells, but it gives a rapid and accurate indication of the levels of contamination at various points, and provides an assessment of the relative numbers of organisms of different types involved.

The second part of the book on scientific control is concerned with the management of the brewing process. A useful addition might have been a chapter on plant instrumentation, as distinct from laboratory instrumentation, and a discussion of the possible applications of automatic control to such parts of the process as might be appropriate.

Apart from a few such points, the book achieves its main object admirably. However, one would have thought it desirable not to interpret "translation" too literally. The purpose of translation from the original French is surely to appeal to English-speaking readers, to whom reference to Belgian Excise Regulations may seem unnecessary, particularly since in some cases the relevant British regulations are not quoted for comparison. The book appears to be almost free of misprints, though the language in parts bears the imprint of the original. This is reflected in occasional grammatical lapses, none of which, fortunately, is so serious as to obscure the intended meaning.

NORMAN BLAKEBOROUGH

Tabellenbuch Chemie

Compiled by Rolf Kaltofen, Ingrid Pagels, Kurt Schumann and Joachim Ziemann

Fried. Vieweg & Sohn, Braunschweig, 1958, 438 pp., DM 17.60.

FEW departmental or sectional libraries contain a copy of LANDOLT-BÖRNSTEIN's "Physikalisch - chemische Tabellen", but this small book will provide much frequently required physico-chemical data. An evening with a dictionary and pencil, if one is not conversant with technical German, will suffice to make the book a useful stand-by, especially since it is well set out and carefully produced.

The contents include such information as the constants for elements and inorganic compounds (atomic weights, molecular weights, melting and boiling points); new nomenclature for inorganic compounds; the constants for organic compounds, including structural formulæ; boiling points of binary and ternary azeotropes; vapour pressures of water and organic solvents; latent heats of vaporisation of organic and inorganic substances; densities of solids and fluids; solubilities of solids in liquids and gases in liquids; degrees of dissociation and dissociation constants of electrolytes; *p*H values of indicators of buffer solutions; some electrochemical equivalents and normal potentials; wavelengths for line spectra; specific heats of elements and

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Book Reviews (continued)

compounds, corrosion resistance of materials; heating values of gaseous, liquid and solid fuels; flash points of dangerous materials; viscosities; coefficients of expansion; explosion limits of gas mixtures and dusts; critical data; and specific resistances of conductors, and insulators.

Subsequent tables are of little interest to chemists and engineers outside Germany, as they refer to safety regulations, colour codes, and standard sieves and filters specific for that country. Tables of five-figure logarithms and temperatures for salt baths are also given. The references set out in the brief bibliography are almost wholly to standard works, most of which are readily available in this country.

W. STRAUSS

Effects of Radiation on Materials

Edited by J. S. Harwood, Hausner, Morse and Rauch.

Reinhold Publishing Co., New York; Chapman & Hall, London, 400 pp., 96s.

THE speed of development in atomic power has largely been controlled by the pace of metallurgical advances and the degree to which current material limitations can be avoided. One of the major problems in this field has been that of radiation damage. This subject has grown rapidly in recent years, particularly since high flux-testing reactors have become available. There are great experimental difficulties because of the problems of handling and examining active materials.

In the "Effects of Radiation on Materials" the authors have presented a valuable series of papers prepared for a Radiation Effects Symposium held in America in 1957. The subject-matter includes the current concepts of the effects of irradiation, the experimental approach to be adopted and the analysis of data at present available. Experimental results are presented covering the irradiation effects on metals, alloys, inorganic materials, dielectrics, semiconductors, organic and polymer materials as well as such specific reactor components as fuel elements, moderators, coolants and shielding materials. Theories and concepts of radiation sources, their effects and measurement are discussed and the observed effects of irradiation on the physical, metallurgical, mechanical, corrosion and electrical properties of materials. This subject is extensive, because it is concerned with many different types of high energy radiation each with its own particular characteristics as a damaging agent and because each of the main types of solid responds to irradiation in its own particular way. G. J. DIENES, in a chapter on the different kinds of disturbance introduced in the structure of a solid by radiation, discusses the production of displaced atoms, drawing attention towards interstitial and vacancy defects with the main purpose of comparing theory and experiment. Chapters by BILLINGTON, HENNIG and WEBER are devoted to the effects of radiation on metals and fuels. The high-energy fission fragments, responsible for damage to metallic uranium, are discussed by WEBER, while the effect of fast neutrons giving rise to metals damage is reviewed by the other authors.

Chapters are included on the general subject of the ionisation effects on solids. These cover the effect of radiation on optical, electrical and para-magnetic properties of materials, while a specialised section by H. Y. FAN covers the effect of radiation on semi-conducting solids. The important phenomena of damage annealing particularly with reference to graphite are adequately covered by HENNIG.

Concluding chapters in this comprehensive volume cover the effects of radiation on the behaviour and properties of polymers and the means of achieving radiation-induced co-polymerisation. This treatment by CHARLESBY and RESTAINO gives a balanced view of the present state of the art, but lends added emphasis to the experimental nature of the work.

The book has been produced to a high standard with a number of valuable illustrations. Careful editing has avoided the overlapping which often mars this type of publication and the book is extremely readable. An excellent and unique feature is the separate and extensive bibliography, which is the first published listing of reference material in this field.

B. E. ELTHAM

The Metallurgy of Vanadium

by William Rostoker

John Wiley & Sons Inc., New York, Chapman & Hall, London, 1958, 185 pp., 68s.

THIS is the second volume in a series on the "Science and Technology of Materials". The author, Dr. William Rostoker (assistant manager of the Metals Research Department of the Armour Research Foundation), is well equipped to cover the subject he has undertaken.

Vanadium is one of those rarer metals which has aroused considerable interest, although so far it has failed to find applications outside of its use as an alloy addition to steel, cast iron, titanium and magnetic and high-temperature alloys. One exception is its use as a lining in the niobium fuel cans for the Dounreay fast reactor.

Dr. Rostoker points out that the state of knowledge of the alloying, physical and mechanical properties of vanadium is far from complete and his book is a progress report intended to indicate some of the properties of the metal in the hope that it may result in further investigations being carried out.

The processes described for the production of vanadium metal include: (1) reduction of oxide by vanadium; (2) thermal dissociation of vanadium iodide by the van Arkel process; and (3) reduction of the chloride.

The chapters on properties and alloy systems are well set out, but give only the briefest information.

The section on the technology of the metal includes everything from melting to welding, but as all this is limited to 20 pages with large illustrations the descriptions are very brief.

"The Metallurgy of Vanadium" is the first book on this subject and is therefore to be welcomed. It sets out clearly, but not always adequately, most of the available information.

G. L. MILLER

Queues, Inventories and Maintenance

by Philip M. Morse

John Wiley & Sons. Inc., New York, and London, 1958, 202 pp., 52s.

THE reviewer believes this to be the first book devoted solely to queue problems and, as such, the author has the advantage of freedom of comparison with other works. However, he would have little to fear in this respect, for the book is very well planned, comprehensive and readable. The author takes care to remind the reader that queue problems are essentially ones which have to be taken on their own merits and for which there are no "rule of thumb" methods. With this end in view, he discusses carefully a wide range of "models", choosing examples from everyday matters such as shopping, filling stations and the telephone service. The translation of these practical problems into mathematical terms is clearly described.

In the earlier sections of the book, only models in which the customer arrival and service distributions are exponential are considered. Later, the author proceeds to discuss in detail ERLANG distributions by means of which some non-exponential forms of these distributions can be expressed in terms of a sequence of exponential service or arrival distributions. Certain other approximations to non-exponential forms are also considered. Particular attention has been paid to practical methods of solving the ensuing difference equations. The book ends with two chapters devoted to the important and special problems associated with stocking and maintenance.

It is not reasonable to expect a book on such a complex subject to be based only on elementary mathematics, but the author has managed to keep the mathematical difficulties to the minimum. The standard of statistics and mathematics required to read the book profitably is about that of the General B.Sc. degree. It might have been better to reduce the scope of the book slightly in order to include rather more explanations of the mathematical basis of the methods.

There are a number of graphs throughout the text, which should prove very useful in practical applications, an appendix containing a number of mathematical tables especially applicable to queue problems and a brief but comprehensive bibliography.

F. FEREDAY

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"Let's tackle this problem once and for all"

SAID THE CHAIRMAN

"We're agreed 'clean air' is here to stay but is this the best way to achieve it?"

"It's not the cheapest—in terms of initial cost at any rate."

"But can we afford to settle for anything cheaper?"

"Afford to? I don't quite follow you."

"I am thinking of terms of power costs, running costs and so on.
You know how maintenance and repairs can run away with the money."

"It still seems a high price to pay."

"Not for long years of trouble-free running.
I suggest, gentlemen, that we tackle our 'clean air' problem once and for all
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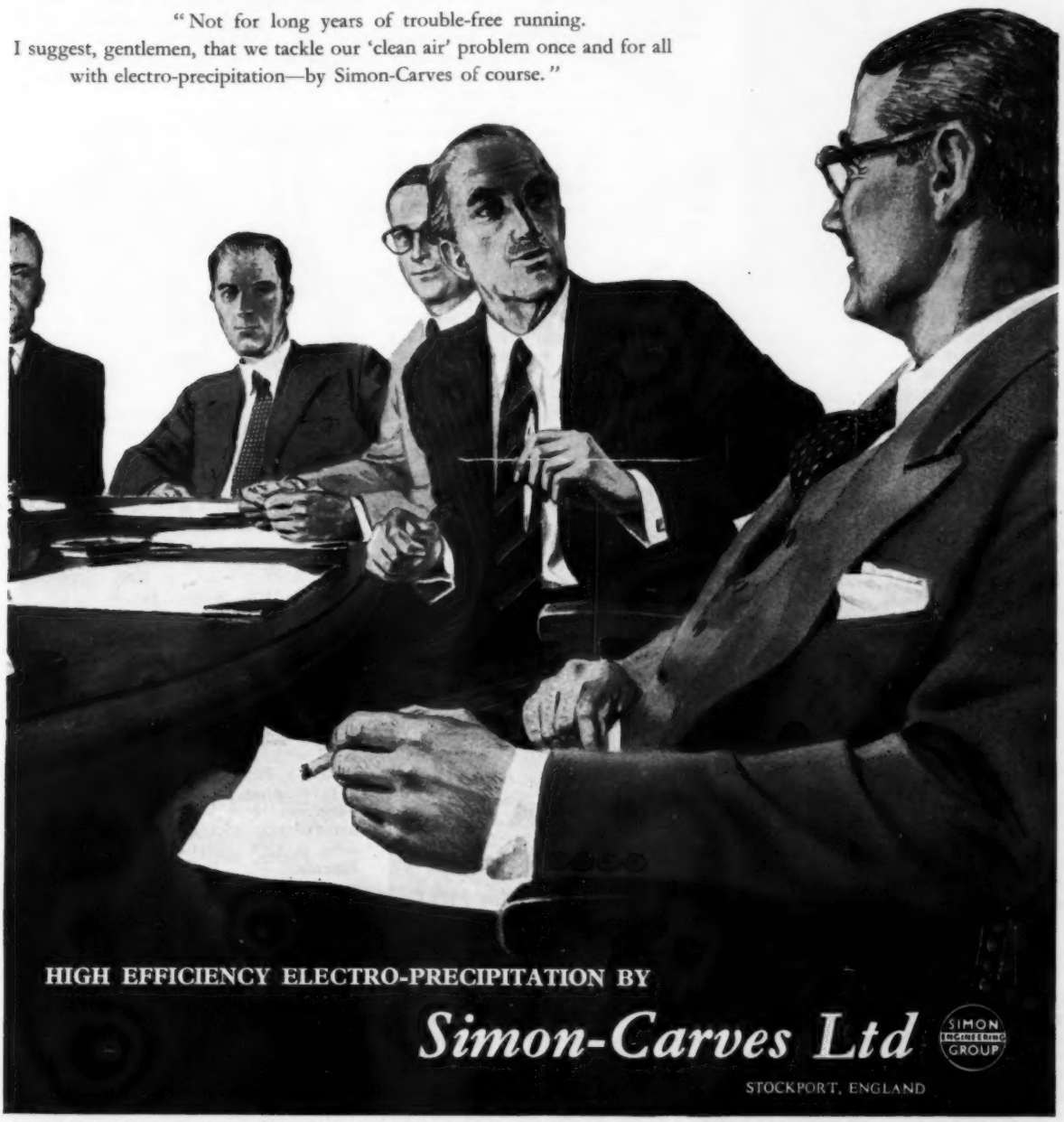

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PLANT EQUIPMENT NEWS

Girdle Pocket Elevator

The girdle pocket elevator by Carl Schenck, Darmstadt, recently made available in Great Britain by Orthos Engineering, consists of an endless folded belt, generally in rubber or a plastics material, held in position by solid side walls, forming equal-sized pockets, which carry the material. The pocket girdle is suspended between two outer belts which alone pass over the driving pulley at the top and bottom. The material which is fed into the inside and discharged from the inside of the girdle does not come into contact with any moving part. The outer drive-belts with drivers are of wire-rope reinforced rubber, and they have practically no stretch. They are also almost noiseless in operation, the makers say. The pockets are filled from either side smoothly by chute or vibro-feeder and they can be discharged on either side on to a belt conveyor. The most economical capacity is 200-10,000 cu. ft per hour. Different sizes of pockets are available. The makers state that the machine will lift vertically fine to coarse-grained heapable materials, whether humid, sharp-edged, warm or abrasive. When fitted with plastic pockets it will handle corrosive materials too. **Orthos Engineering Ltd., 4 Mosley Street, Newcastle upon Tyne, 1.**

BCE 4323 for further information

Variable-pitch Cooling Fans

Rotol have elaborated a basic design of cooling fan hub for the adjustable pitch capable of ready conversion to controllable pitch by the addition of a control cylinder assembly and anti-friction bearings in the fan blade mounting. The design permits this conversion without any additional machining to the basic adjustable pitch hub. The design affords direct interchangeability between hollow steel or laminated plastic blades. The company will use a test rig to ensure that all fan performance data submitted to customers are based on measured values from full-scale fans. **Rotol Ltd., Cheltenham Road, Gloucester.**

BCE 4324 for further information

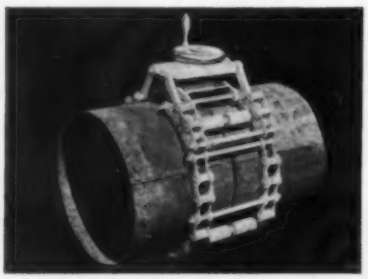
Weather- and Flame-proof Motors

A new type of weather- and flame-proof totally-enclosed fan-cooled motor to form an intermediate range between KFB and FSP (or HFSP) machines has been introduced by Metropolitan-Vickers. The new type covers the 50 hp to 200 hp low tension and 50 hp to 125 hp high tension ranges. The number of frame sizes has been kept to two. The new frame sizes have been designated type HKFP 6360 and 7872 for two-pole speed and the KFP 6360 and 7872 for the four-pole and slower speeds. The new machines have been developed with a view to the specialised requirements of the oil and chemical industries for which they are intended. The final design conforms with the specification issued by the Oil Companies Materials Committee and with the relevant British Standards. The construction of the motors has been certified as flame-proof by the Ministry of Power for Groups I, II or III gases. **Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester, 17.**

BCE 4325 for further information

Pipe Clamps

Courtburn are now manufacturing to their own design a range of adjustable pipe clamps which will accommodate a wide range of pipes. Each model caters for all pipe sizes over a 6-in. range, and quickly holds and aligns the pipes externally for butt welding. At present three sizes of clamp are available to accommodate pipes from 6 in. to 24 in. in diameter, but larger sizes can be

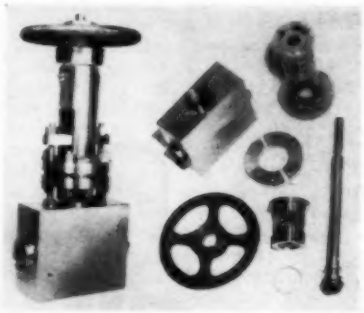


made if required. In use, the clamp is wrapped around the two butted pipe ends to be welded, double claws are engaged on the nearest distance piece, and the handwheel turned until the clamp grips the pipe ends in perfect alignment for butt welding. Ample accessibility is provided for tacking all round the pipes, the makers state, and space can be left between the pipe ends for the weld filler as required. **Courtburn Positioners Ltd., Kempston Hardwick, Bedford.**

BCE 4326 for further information

High-temperature Valve

The Gyp high-temperature valve A.575, originally designed for special requirements in the atomic field, has been introduced generally to meet the requirements for a valve to handle liquids and gases at temperatures up to 600°C. Sizes from ¼ in. to 2½ in. are available, and they can be supplied as control valves for metering flow or as normal shut-off valves, with renewable seats and plugs.



Other features can be varied to suit customers' requirements. Intended for use where erosion and corrosion are major problems, the new Sulfinux process is employed in the manufacture. **High Pressure Components Ltd., Sunflex Works, Colham Mill Road, West Drayton, Middlesex.**

BCE 4327 for further information

Wire-wound Tubes

The latest additions to Clayton Dewandres range of wire-wound heat-transfer tubes include a brazed model, for use at working temperatures higher than those of the soldered tubes. It is of 1¼ in. o.d. with mild-steel wire brazed on ¼-in. o.d. mild-steel tube. The surface ratio is 12.1:1. A heavier welded model, primarily for atomic power duties, is also being made. This is 2¼ in. o.d. 16 s.w.g. mild-steel wire welded on 1¼ in. o.d. 10 s.w.g. mild-steel tube. Its surface ratio is 13:1. **Clayton Dewandre Ltd., Lincoln.**

BCE 4328 for further information

Cylinder-operated Valves

A range of cylinder-operated valves has been introduced by Maxam Power, designed to ensure positive movement of the valve member under extremes of operating conditions. They are single- or double-cylinder operated, two-, three- or four-way in design and in size, $\frac{1}{16}$ in. and ¼ in. The large piston area provided by the cylinder gives a greater thrust to the valve sliding member, an important safeguard against out-of-sequence operation

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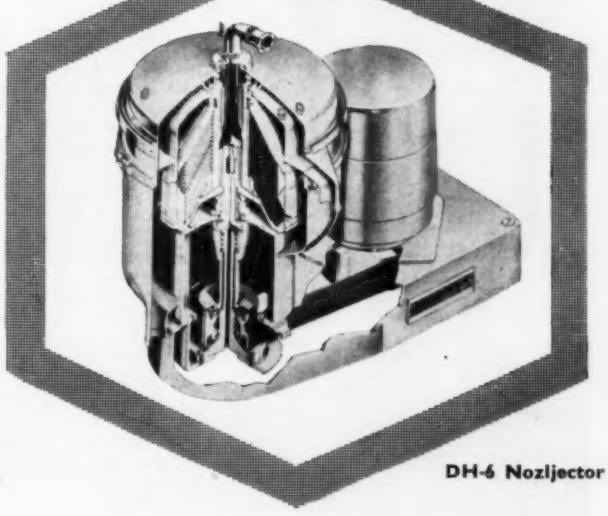
Only Sharples can offer a centrifuge for every problem including a complete range of disc centrifuges, three of which are the Controlled Solids Discharge DV-2 Centrifuge, the DG-2 Autojector and the DH-6 Nozljector.

The Controlled Solids Discharge DV-2 Centrifuge purges solids from the bowl continuously by means of valves which are controlled by an external timer. Instantly variable control of solids discharge is thus at the operator's fingertips.

The DG-2 Autojector. In this case build up of solids in the bowl automatically opens the valves, which allows the DG-2 to handle variable feed material. Consistent operation without attention is ensured by this unique design.

The DH-6 Nozljector has the largest capacity of the Sharples range of nozzle discharge disc centrifuges. In fact it has a higher capacity than any other machine of this type in the world.

DG-2 Autojector



DH-6 Nozljector

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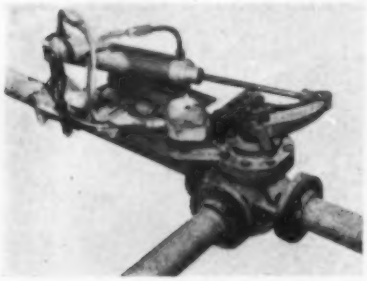


resulting from, for example, adverse weather conditions, the makers point out. One of the installations of these valves which entails the control of the flow of china clay slurry, is shown. The valve is immediately below the air cylinder. **Maxam Power Ltd., Camborne, Cornwall.**

BCE 4329 for further information

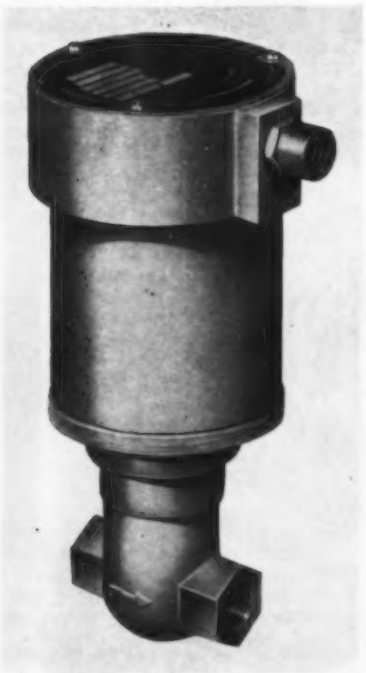
Graphite Heat Exchangers

To their range of graphite heat exchangers, Powell Duffryn have added a model with 300 sq. ft of heat-exchange area. There are now thirty standard models in the range, from 4 sq. ft to 300 sq. ft in heat-exchange area. **Powell Duffryn Ltd., 8 Great Tower Street, London, E.C.3.**

BCE 4330 for further information

Solenoid Valve

Ether's new products include their type HPO solenoid valves designed for applications where oil viscosity is likely to exceed 200 seconds Redwood No. 1. Non-standard versions, for operation



with other high-viscosity liquids or at working temperatures in excess of the maximum for standard models, can be supplied to order. A powerful solenoid, with a newly designed plunger assembly, ensures a maximum lift under adverse conditions of viscosity, the makers point out. Their new type RA solenoid valve is suitable for low flow and pilot applications where control of a gas or low-viscosity liquid is required. **Ether Ltd., Solenoid Valve Division, Caxton Way, Stevenage, Herts.**

BCE 4331 for further information

Bagging Valve

The Sureseal bagging valve has been introduced by Barron, who draw attention to its immediacy of action due to two pneumatically-operated cylinders

sealing or opening a 6-in. diameter flow line, and to its provision of full-bore passage without impediment. Designed to ensure the elimination of spillage, it is totally enclosed, and it may be remotely controlled by manually- or electrically-operated valves. **W. S. Barron & Son Ltd., Gloucester.**

BCE 4332 for further information

Catalytic Sulphur-removal Plant

The Holmes catalytic sulphur-removal plant will remove 70-80% of organic sulphur from towns gas, it is claimed. The gas is heated to 300°C and passed through a bed of catalyst where the temperature rises to about 365°C, thermostatically controlled. Hydrogen in the fuel gas reacts with the organic sulphur compounds producing carbon which deposits on the catalyst, and hydrogen sulphide. The gas passes to an air cooler, and finally through a purifier containing iron oxide where the hydrogen sulphide is removed. The process is normally operated at atmospheric pressure, but can operate at pressures up to 200 psi. The iron oxide in the purifier is revivified from time to time by switching it over to the untreated gas. For this purpose two purifiers are provided with the necessary interconnections and valves. The spent catalyst is then removed after a few months and a new batch inserted. The catalyst may be regenerated by the user or returned to Holmes for treatment. **W. C. Holmes & Co. Ltd., Turnbridge, Huddersfield.**

BCE 4333 for further information

Automatic Dust Collector

A mineral type of filtration medium is used instead of textile filter tubes in the new Bermax automatic dust collector, of German design, for which Visco Engineering have acquired the manufacturing rights. It is particularly suitable, Visco point out, for use in high-temperature conditions, for the recovery of dust having no commercial value, or for dust to which slight contamination by the filter medium would be of no importance. Each compartment of the collector houses a spring-mounted filter bed consisting of a primary cell filled with steel shavings and a secondary cell filled with stone chippings graded according to the dust loading and particle size of the material handled. Each filter bed is connected directly to a shaker motor mounted externally.

An isolating damper is fitted to each compartment, all the compartments being connected to the common cleaned gas exhaust header. Each damper is operated by a compressed air cylinder controlled by a solenoid valve from an automatic control panel. The frequency of the cleaning cycle may be varied to suit individual conditions.

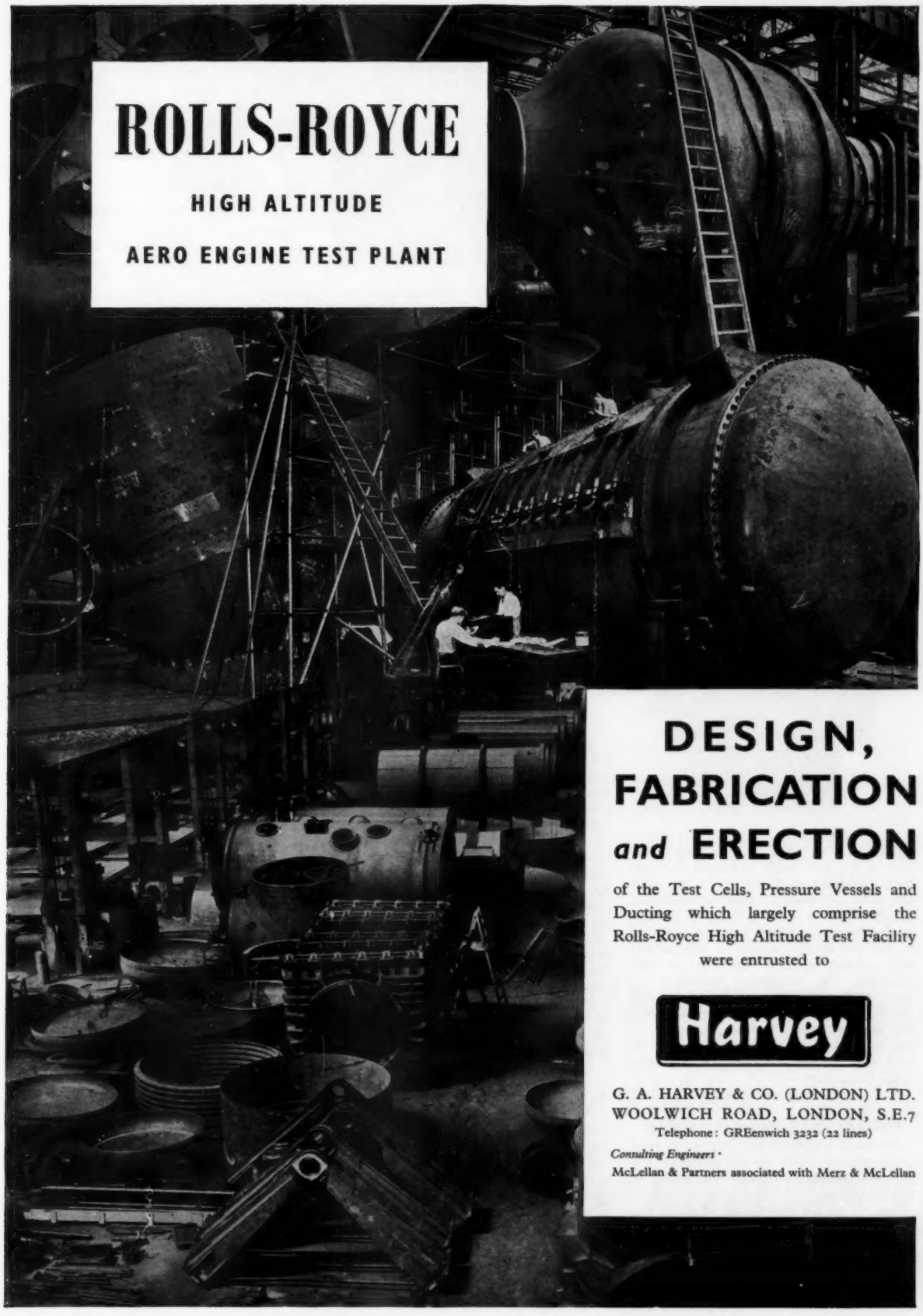
The standard dust collector is designed to handle gases up to 120°C, but by the provision of certain special parts, gases with temperatures up to 400°C can be dealt with. The pressure drop across the collector, it is said, is 2½-4 in. s.w.g. according to the gas loading and the depth and grading of the secondary medium.

The makers state that a typical installation with a capacity of 5000 cfm handling dust-laden gases from a lime kiln in a cement works achieved a collection efficiency of 95%. The dust content of the unfiltered gas was 7.25 grains/cu. ft. and that of the filtered gas 0.035 grains/cu. ft. **The Visco Engineering Co. Ltd., Stafford Road, Croydon.**

BCE 4334 for further information

Range of Valves

The Farris range of safety-relief valves and pinch-type Flex valves is to be manufactured by a new company, Farris Engineering Ltd., and sold in Europe, the British Commonwealth (except Canada)



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of the Test Cells, Pressure Vessels and Ducting which largely comprise the Rolls-Royce High Altitude Test Facility were entrusted to

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PLANT EQUIPMENT NEWS

and the Middle East, as the result of the signing of agreements between Associated Automation (a subsidiary of Elliott-Automation) and Farris Engineering Corp., New Jersey, and Farris Flexible Valve Corp.

Farris valves are used in the petroleum, gas and chemical industries. The Flex valves are corrosion resistant and designed for use with slurries and where grit is present. They can be both automatically and manually operated. **Elliot-Automation, Century Works, Lewisham, London, S.E.13.**

BCE 4335 for further information

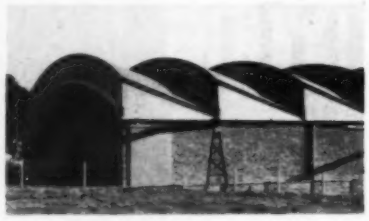
Rotary Air Pumps

Williams & James recently introduced rotary exhausters and air pumps of the vane type, suitable for continuous duty at 15 in. vacuum or 7.5 psi pressure and 20 in. vacuum or 10 psi pressure on intermittent duty. The rotor casing is of best grey iron, with a honed finished bore, Williams & James point out, and the rotor, of nodular iron, is machined in one with its driving shaft. It is supported by large journal ball races located in the end covers, which are pre-packed with grease to last the life of the machine. The lubricated machines require oil for the fibre vanes but the "oil-free" types require no lubrication for the carbon vanes. The displacement of the various models ranges from 9.3 to 41.6 cfm. **Williams & James (Engineers) Ltd., Gloucester.**

BCE 4336 for further information

Prefabricated Large-span Buildings

Patented prefabricated large-span roof constructions based on the German Silberkuhl design are now available in Great Britain from the recently-opened extension to the factory of Modern Engineering (Bristol) Ltd. The roofs, which are made in conjunction with A.T.A. Industrial Co. Ltd., consist of composite steel and concrete constructions providing clear spans of up to 210 ft, and



loading capacities of 15 tons from any point of the roof. A particular advantage claimed for them is the speed of erection, shuttering on the site, for example, being eliminated. The roofs are said to be competitive in price with conventional steel roofs, and the cost of complete buildings is put at £2 per sq. ft. Roof sections can be arranged in a variety of ways, the most generally useful being that illustrated, with the sections sloping. Abundant daylight is obtained from the north-lighting, and, on experience in Germany, it is claimed that adequate ventilation, even for processes that produce steam or other vapours, is obtained naturally by fixing a duct at the centre of the arches. A second design of prefabricated roof also being made by Modern Engineering is the A.T.A. hyperbolic shell. These are prestressed concrete shells, with spans of up to 65 ft. **A.T.A. Industrial Co. Ltd. and Modern Engineering (Bristol) Ltd., Emery Road, Bristol, 4.**

BCE 4337 for further information

Liquid Heat Pump

Temperature Ltd. are now producing a range of automatic liquid heating plants using a hermetically sealed air-to-liquid heat pump. The pumps can operate over a wide range of conditions to suply 150 gal. per hour of liquid at temperatures up to 120°F, and by using heat from the outdoor air, even at lowest winter temperatures, the equipment will provide heating equivalent to two and a half times the total watts absorbed by the machine, the makers say. The circulating pump has a neoprene impeller, and will handle a variety of liquids at external heads up to 30 ft. The rating of each unit varies according to the required water temperature; a typical duty would be 18,500 Btu/hr. with outdoor air at 40°F. **Temperature Ltd., Burlington Road, London, S.W.6.**

BCE 4338 for further information

Magnetic Clarifier

As a result of the development by Philips of ceramic magnetic materials, the company has produced a drum for coolant clarifiers, magnetic over its entire surface. It is claimed that the magnetic field is so intense and the fluid to be filtered so controlled in the company's new range of Magna-Drum clarifiers that a high proportion of grinding abrasive is always contained in the swarf collected on the drum's surface. The swarf is removed by specially designed scrapers. Straight cutting oils or soluble oil coolants can be filtered without modification to the machine. The drum itself is about 6 in. in diameter. The range is designed to handle flows of 300-5000 gph. **Philips Electrical Ltd., Century House, Shaftesbury Avenue, London, W.C.2.**

BCE 4339 for further information

Instruments

Mercury-vapour Meter

Advantages claimed for Engelhard's new mercury vapour meter include its ability to be operated on any supply voltage in the range 200-250 volts, 50 cycles, A.C., without adjustment; its zero and deflection being independent of changes in line voltage; and the ability to preset its operation at any level within the range of the instrument. Two ranges of sensitivity are provided: (*a*) zero to 200 μ G cu. m.; (*b*) a × 2. **Engelhard Industries Ltd., Hanovia Lamps Division, Bath Road, Slough.**

BCE 4340 for further information

Magnetic Dipstick

The new F-R magnetic liquid-level indicator or contents gauge is designed to be suitable for all forms of liquid containers. The instrument consists of a dipstick coupled magnetically to a float in the tank. When not in use the dipstick is positively locked into its mounting flange. It permits, the makers point out, accurate measurement unaffected by specific gravity, without disturbing tank seals and it is therefore particularly useful for pressurised tanks. As the risk of spillage, evaporation, explosion or liquid contamination is eliminated, it is very suitable too for use with corrosive, inflammable and highly volatile liquids. The indicators can be supplied in a number of different sizes with dipsticks calibrated to suit particular tank requirements. The instrument is a development of an aircraft model. **Flight Refuelling Ltd., Tarrant Airfield, Blandford, Dorset.**

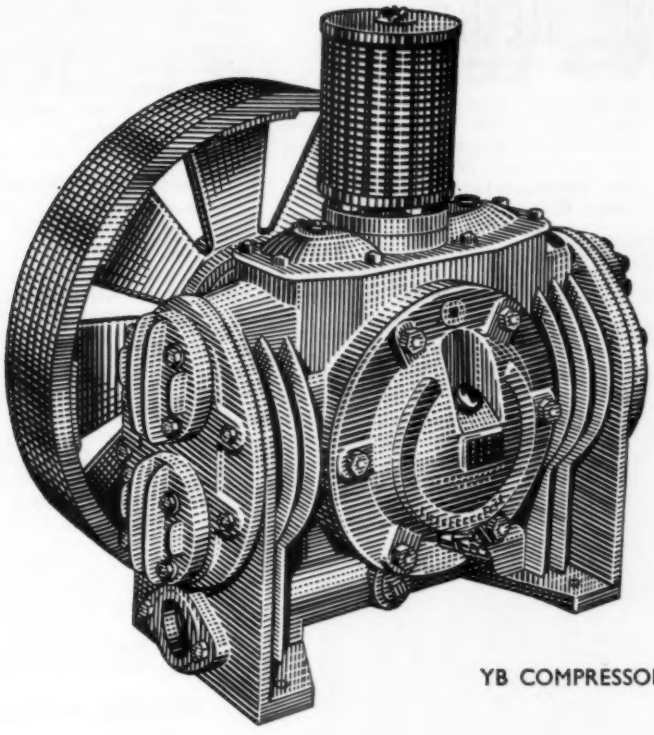
BCE 4341 for further information

Indicating Flowrator

In the Fischer & Porter model 2700 indicating flowrator recently introduced, rubber "O" rings seal the tube ends to the metal end fittings incorporated in the metal body. The body is a robust assembly of mild steel pressings obviating the need for bolts and screws, it is pointed out, and a few of the benefits claimed for this method of construction are as follows: The metering tube is isolated from pipeline stresses; it can be snapped in without the use of tools and without disconnecting or disassembling the meter; and range changing and cleaning are therefore simple and quick. The meter withstands high pressures.

At first the instrument will be available in two frame sizes, allowing 10:1 ranges to be provided from a maxima of 3-30 cc./min. air and 0.35-3.5 cc./min. water to maxima 4-40 scfm air and 50-500 Igph. A third size of meter frame will later be placed on the market. **Fischer & Porter Ltd., Salterbeck Trading Estate, Workington, Cumberland.**

BCE 4342 for further information



YB COMPRESSOR

this pump is ideal for all low pressure work...

In this YB Series of twin-cylinder, air-cooled compressors, for pressures up to 50 lb./sq. in., there are several sizes with motors varying from 1½ to 10 H.P. As specialists in the design, manufacture and performance of vacuum pumps, and compressors up to 3,600 lb./sq. in., Lacy-Hulbert can help with your problems of application and installation. When ordering or writing for leaflet please state application and quote Ref. YB/23.

✻

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PLANT EQUIPMENT NEWS

Electronic Thermo-switch

A new electronic thermo-switch being made available by A. M. Lock provides an on/off control action on a temperature differential of ±0.1% of range coverage, and is usable in the temperature range −200°C to +500°C, the manufacturers point out. It will fail to safety as required. **A. M. Lock & Co. Ltd., 79 Union Street, Oldham, Lancs.**

BCE 4343 for further information

Magnetic Float Gauge

The new Lipton magnetic float gauge has been designed for a wide variety of applications. It will withstand high pressures and is accurately counterbalanced, the makers point out, for possible operation in liquids of low specific gravity such as L.P. gas, etc. It is hermetically sealed, is submersible and can be calibrated to individual requirements. The gauge is available for top, side, end or angle mounting. **L.P. Carburettor Co. Ltd., Wooburn Green, Bucks.**

BCE 4344 for further information

Fluorescent Testing

The Hanovia ultra-violet fluorescence lamp, model 17, has been developed for the non-destructive testing of large components using fluorescent ink methods. It is intended to supplement their small model 16. Its rectangular metal housing, contains a 2-kW medium-pressure mercury vapour lamp mounted between the reflector and the heat-resistant filter glasses for suspension over an inspection bench. A centrally mounted fan on the top of the housing draws in cooling air and distributes it evenly so that the warm air is exhausted through the inverted ducts at each end. Ultra-violet filter glasses fitted to the underside of the lamp are heat resistant and transmit about 75% of the light in wavelength regions

of 3650 A.U. With the lamp 5 ft. from the area to be viewed, distinctive fluorescence is obtained along 11 ft of the central main axis of the lamp, Hanovia state. **Engelhard Industries Ltd., Hanovia Lamps Division, Slough, Bucks.**

BCE 4345 for further information

Adhesive Plastic Scales

Graduated transparent adhesive tapes which, when affixed to gauge glasses, glass tubes or vessels, etc., have the appearance of engraved scales, are being marketed by Scalafix. Of vinyl plastic pvc., they are resistant to water and many chemicals. They are printed in continuous lengths of 56 cm. and can be combined to give any length of scale required. The tens above 50 can be overstuck with numbers cut from an auxiliary strip, and the scales are available to read upwards or downwards. Patents have been

applied for for the product, which is available in 36-yard rolls which provide about sixty 50-cm. scales. Non-transparent graduated adhesive tapes are also available and specially graduated tapes are supplied to special order. **The Scalafix Co., 20 Outwoods Drive, Loughborough, Leics.**

BCE 4346 for further information

Multi-point Recorder

A new multi-point recorder which provides a permanent printed record of variable inputs, e.g., temperature, strain, d.c. input, etc., from any one of 500 points, the time at which the measurement was taken and the channel identification is being produced by Savage & Parsons Ltd. The temperature extension unit contains the terminal connection blocks wired (with thermocouple wire) through a 50-way switch to a "cold junction" which is in a well-lagged thermostatically-controlled oven. The temperature of this oven is kept fairly low to further minimise losses, and consequently assist accurate control. The 50-way switch is automatically advanced one position each time the main recorder reaches the balance, and this also operates the printing mechanism. At the same time the channel identification is altered. When the complete number of inputs has been recorded the main unit input is automatically switched on to the next extension unit. **Savage & Parsons Ltd., Watford, Herts.**

BCE 4347 for further information

Temperature Measurement

Fielden Electronics announce new equipment for temperature measurement using thermocouples which incorporate their new series of D.C. amplifiers and which they describe as simple, accurate and reliable. When used with a circular scale moving coil indicator of B.S.I. precision grade, the overall accuracy of the whole equipment can be better than 0.25% even on 2½-millovolt ranges, and the indicator, it is claimed, has all the advantages of potentiometric equipment in so far as it is independent of lead resistance. **Fielden Electronics Ltd., Wythenshawe, Manchester.**

BCE 4348 for further information

The order of precision of the ETL-NPL automatic polarimeter, by Ericsson Telephones Ltd., 22 Lincoln's Inn Fields, London, W.C.2, is 0.0002 degree of arc, and not as stated in our note in BRITISH CHEMICAL ENGINEERING, October, p. 580.

Materials and Coatings

Resin-glass Laminate

Prodorite are now able to supply constructions for use in chemical plant in Orglas super resin-glass laminate. Among the chemicals that it resists is hydrofluoric acid 10%, and the material is described as having good resistance to caustic alkalis. **Prodorite Ltd., Eagle Works, Wednesbury, Staffs.**

BCE 4349 for further information

Phosphate Coating

The cold Bonderite system, established in the U.S.A. for protecting metallic surfaces with a zinc phosphate coating which inhibits corrosion and increases the durability of paint finishes, is now available in Great Britain through the **Metal Finishing Division of The Pyrene Co. Ltd., Great West Road, Brentford, Middlesex.**

BCE 4350 for further information

Bright Nickel Plating

The Plusbright bright nickel plating originally developed in the United States by the Hanson-Van Winkle-Munning Co., where it is known by the names Nickel-Lume and Levelume, is being marketed in the United Kingdom by **Albright & Wilson. (Mfg.) Ltd., 1 Knightsbridge Green, London, S.W.1.**

BCE 4351 for further information

Epoxy Finishes

Sandeman's E.P.C. finishes are based on media derived from epoxy resins. Two main types are available: those based on esterified epoxy resin, and Sandeman's recommend these for the protection of structural and plant steelwork, where ordinary paint has failed; and those based on amine-cured epoxy resins. When applied to a surface their curing pro-

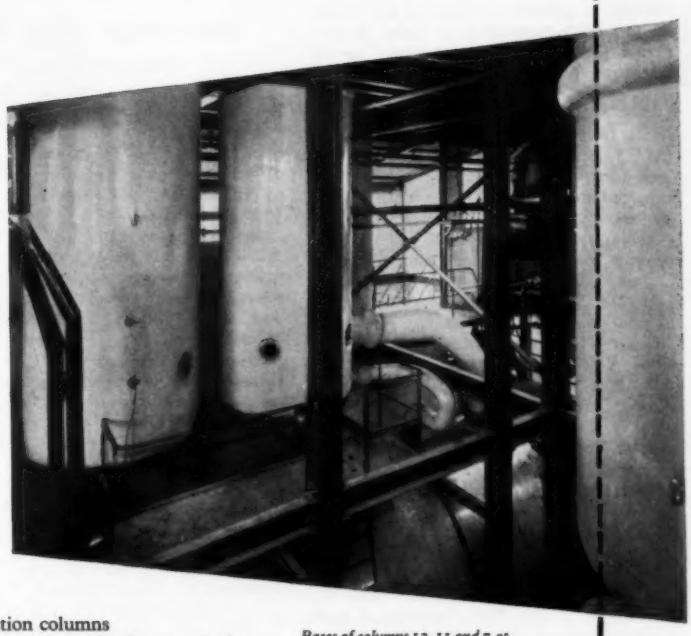
BCE 4262 for further information

stainless steel columns-

-for TAR ACID DISTILLATION

by

R. Graesser Ltd.,
Sandycroft



Bases of columns 12, 11 and 7 at Sandycroft. Columns of stainless steel to B.S.S. En58B, trays En56A.

The second and third stainless steel distillation columns designed and manufactured by Metal Propellers Ltd. for R. Graesser Ltd., Sandycroft, have recently gone on stream in the production of tar acid fractions, and a fourth column is now in course of manufacture.

All four columns are of 5′ 0″ dia. and are fitted with Glitsch "Truss-Type" Bubble Trays and each handles boil-up at a minimum design rate of 750 g.p.h. tar acids.

Stainless steel distillation column of light-weight construction 5′ 0″ dia. x 56′ 0″ long, supplied complete with Glitsch bubble trays.

Tar acid refiners for Lancashire Tar Distillers Ltd., R. Graesser Ltd. enjoy a unique reputation for their production of super quality tar acid fractions such as pure phenol, orthocresol, etc. Their alloy steel columns, amongst the largest units on tar acid duty in this country, ensure products of pale colour, with minimum thermal degradation due to low tray pressure drop, and free from iron contamination.

Metal Propellers Ltd.

STAINLESS STEEL SPECIALISTS

74 PURLEY WAY, CROYDON, SURREY Thornton Heath 3611-5

HP37

PLANT EQUIPMENT NEWS

ceeds at ambient temperatures to give a finish equal, Sandeman state, to a stove finish. Their use is suggested for the coating of objects too big to be stoved or too surface-sensitive to heat. **Sandeman's Varnish Ltd., Murano Street, Glasgow, N.W.**

BCE 4352 for further information

Polyurethane Rigid Foam

I.C.I. Dyestuffs Division state that their introduction of Daltolac 24 extends the range of densities which can be achieved by foaming *in situ* techniques using the two-component polyurethane foam systems, the organic isocyanate Suprasec D being the other component in each case. Daltolac 24 contains fireproofing agent, a catalyst and other additives. **Imperial Chemical Industries Ltd., Dyestuffs Division, I.C. House, Millbank, London, S.W.1.**

BCE 4353 for further information

Corrosion-resistant Ductwork

High-impact P.V.C. for ductwork, known as Manmil P, is being made available by **M.M. Plastics Ltd., Castle Street, Stalybridge, Ches.**

BCE 4354 for further information

Magnesium Alloy

J. Stone & Co. have introduced new magnesium-base alloys containing silver, rare earth metals and zirconium and known by the initials M.S.R. (A) and M.S.R. (B). Intended for casting, these alloys are distinguished by proof stress values at levels hitherto attainable only with aluminium-base alloys, Stones state, and castings are being offered in material conforming to two tentative specifications which are as follows:

	A		*B*
0.1% Proof stress, tons/sq. in., not less than	10	...	11
Ultimate tensile stress, tons/sq. in., not less than	15	...	15
Elongation, per cent, not less than	4	...	2

The density of the alloys is 1.82 gm./cc. They are said to exhibit good resistance to creep at about 200°C, to be weldable, and not liable to stress-corrosion failure. The producers are licensed by Magnesium Elektron Ltd. **J. Stone & Co. Ltd., Oceanic House, 1a Cockspur Street, London, S.W.1.**

BCE 4355 for further information

Creep-resisting Alloy

Nimonic 105 is a development of the nickel - chromium - cobalt - molybdenum alloy Nimonic 100 and has greater resistance to creep at very high operating temperatures than it, the minimum life to rupture at 7 tons per sq. in. and 940°C (1724°F) being 50 hours. It also shows improved resistance to a type of high-temperature corrosion sometimes experienced in aero and other gas turbines running at elevated gas temperatures and associated with contamination by solid or molten sulphates. **Henry Wiggin & Co. Ltd., Thames House, Millbank, London, S.W.1.**

BCE 4356 for further information

New Foreign Equipment

Titanium Alloy

Crucible Steel's new titanium alloy B-120VCA has a composition of vanadium, 13%; chromium, 11%; and aluminium, 3%. In its soft, formable, condition it has a minimum yield strength of 120,000 psi, but ageing the product from 20 to 100 hours in the 850-950°F range strengthens it to the 170,000-200,000 psi yield strength range with good residual ductility, and considerably higher strength values than these are possible with some reduction in ductility, the makers state. For a short time (1-2 minutes) of the tensile test, B-120VCA shows a strength-weight advantage over alternative materials up to at least 1000°F. For a longer test period such as 500 hours, VCA shows a strength-weight advantage up to at least 600°F and this probably extends to 700°F and possibly to 800°F. Beyond this limit other alloys are more suited. Its resistance to corrosion is said to be like that of other alloys. **Crucible Steel Co. of America, Titanium Division, Midland, Pa., U.S.A.**

BCE 4357 for further information

Ferromanganese-Silicon

Substantial savings in the production of high-manganese stainless steels are now made possible by using ferromanganese-silicon, a new alloy now available from the Alloys and Metals Department, Union Carbide International Co., Division of Union Carbide Corp., the company states. The analysis of ferromanganese-silicon is 63-66% manganese, 28-32% silicon, 0.10% maximum carbon, 0.05% maximum phosphorus and 0.03% maximum sulphur. **Union Carbide International Co., Alloys and Metals Department, 30 East 42nd Street, New York, 17, N.Y., N.S.A.**

BCE 4358 for further information

Pipe Joint Assembly

The Marman Conoseal tubing joint, designed to maintain a leakproof seal under the most adverse operating conditions in the chemical and oil industries, retains a perfect seal from −300°F to +1800°F and at pressures up to 6000 psi, the makers state. It requires the securing of only two bolts to put it together, and the seal is maintained with axial deflections of up to $\frac{1}{16}$ in. The joint is available in three performance ranges to meet requirements, and special sizes are supplied to order. Now the joint is being specified on liquid sodium and other special fluids where previous methods required welded systems for perfect seals, and it is being used successfully, Marman state, to join pipes of dissimilar metals. **Aeroquip Corp., Jackson, Michigan, U.S.A.**

BCE 4359 for further information

New Publications

A folder outlining the Burstlein-Longwy process of coal preparation and illustrating the Algiers gasworks and the Thionville and Pont-a-Mousson coking plants is available from **Woodall-Duckham Construction Co. Ltd., 63 Brompton Road, London, S.W.1.**

BCE 4360 for further information

The autumn number of *Appleby-Frodingham News* is a special souvenir issue of the Royal visit to the Appleby-Frodingham Steel Co. on June 27, 1958. The 48 pages are devoted mainly to photographs taken during the tour of the Queen and the Duke of Edinburgh round the various sections of the works. **Appleby-Frodingham Steel Co., Scunthorpe, Lincs.**

BCE 4361 for further information

A new 12-page catalogue describing the recently-introduced Class F.E. range of horizontal, double-acting, balanced, opposed compressors has been produced by Consolidated Pneumatic Tool. Details of design, application and operation and specifications of operating examples are included. The publication is illustrated with half-tone pictures and line diagrams. The introduction outlines considerations of design involved in eliminating vibration. **Consolidated Pneumatic Tool Co. Ltd., 232 Dawes Road, London, S.W.6.**

BCE 4362 for further information

Design and performance details of a range of small Tornado fans and blowers for ventilating and cooling industrial equipment are provided in a new folder from **Keith Blackman Ltd., Mill Mead Road, London, N.17.**

BCE 4363 for further information

Hilger & Watts have published a series of illustrated booklets dealing with, respectively, their recording *X*-ray diffractometer and fluorescence spectrometer; their Microfocus *X*-ray unit; their wavelength spectrometer; and (by agreement with N.V. Evershed-Enraf) the Enraf *X*-ray source units. **Hilger & Watts Ltd., 98 St. Pancras Way, London, N.W.1.**

BCE 4364 for further information

Recent publications from Weir include four-page brochures on their QB and SD turbine-driven feed pumps. **G. & J. Weir Ltd., Cathcart, Glasgow, S.4.**

BCE 4365 for further information

"Gas Treatment, Gas and Liquid Storage" is a ten-page illustrated brochure recently published by Whessoe. Among the plant dealt with are gas coolers and condensers, electro-detarrers, multi-stage scrubbers and hydrogen-sulphide extraction plant. **Whessoe Ltd., Darlington, Co. Durham.**

BCE 4366 for further information

T.I.'s contribution to the nuclear engineering industry is described in a 23-page booklet in two colours. It describes the activities of T.I. companies in the nuclear engineering industry and the range of nuclear engineering equipment and components they supply. **T.I. Nuclear Engineering Ltd., The Adelphi, London, W.C.2.**

BCE 4367 for further information

Single reduction fan-cooled Worm Gear Unit Type SUH.

Illustrated is one of a range of robust reduction gear units manufactured by us at Newbury. Capable of transmitting powers up to 120 h.p., this type of unit has proved to be ideal in iron and steel manufacture, mining, chemical engineering, paper making, textiles and wherever power transmission is employed.

We manufacture reduction gear units for so many applications it would be difficult to enumerate them in this advertisement, but we will be pleased to send you particulars on request.

We will gladly design and produce reduction gear units to your individual requirements—your enquiries will be welcomed at Newbury.

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Month's News in Brief

Spondon Expansion

The oil cracking plant at the Spondon, Derby, factory of British Celanese is to be expanded by approximately 40% of present capacity. The plant produces ethylene and propylene and from them a wide range of petrochemicals. Work has already begun and completion is expected in nine to twelve months. The expansion will incorporate a very extensive use of automatic control and recording apparatus. Chemical products other than those based on petroleum are also manufactured on the same site. These, too, are being further developed in accordance with Courtaulds' widening interest in the whole chemical field. The British Celanese plant, which began operating in 1942, was the first U.K. plant to produce alcohols and petrochemicals by the cracking process. Previously, U.K. production of ethanol had been based almost wholly on fermentation of imported molasses. Other new projects recently authorised at Spondon include the manufacture of an improved quality of cellulose acetate flake for the plastics industry; extensions are also nearing completion to methyl cellulose production capacity. This product is finding an increasing use in wallpaper adhesives, food thickeners and paint.

C.B.M.P.E. Dinner

Dr. James Taylor, M.B.E., D.Sc., a director of Imperial Chemical Industries Ltd. and chairman of Yorkshire Imperial Metals Ltd., was the chief guest at the annual dinner of the Council of British Manufacturers of Petroleum Equipment held in London recently. The dinner was attended also by diplomatic representatives of nine countries and by over 1200 members and friends. In the course of his speech, Mr. G. H. Thorne, chairman of the Council, urged all members to be represented at the fifth World Petroleum Congress to be held in New York in June, 1959.

News in Brief

Construction work on Britain's first Lurgi pressure-gasification plant began on the Scottish Gas Board's site at Westfield on the border of Fife and Kinrossshire on October 24, 1958 (see p. 690).

The Board of Booker Bros., McConnell & Co. Ltd. announce that Bookers Engineering Holdings Ltd. (a member of the Booker Group of Companies) has purchased 90% of the issued share capital of Sigmund Pumps Ltd. from members of the Sigmund family and from the Industrial & Commercial Finance Corporation. Mr. Mirsolav Sigmund, the managing director of Sigmund Pumps, retains a 10% interest in the company and remains managing director. The present management of the company will continue, as at present, at Team Valley, Gateshead. The new board of Sigmund Pumps Ltd. will consist of: Mr. E. N. Robinson, chairman; Mr. M. Sigmund, managing director; Mr. G. R. Glendinning, secretary; Mr. D. W. L. Menzies; Mr. C. W. Tyrrell; Mr. P. Parker; and Mr. H. P. Lord.

Technicon International Ltd., of New York, announce the formation of a British subsidiary company, Technicon Instruments Co. Ltd. with offices at 26 Warwick Road, London, S.W.5 (Tel.: FREmantle 5109). The company will manufacture and market in the United Kingdom and Commonwealth the "Auto-Analyzer" for automatic continuous chemical analyses for production control, as well as the other Technicon products.

A plant costing £800,000 for the production of dyestuffs is to be built at the works of The Clayton Aniline Co. Ltd., at Clayton, Manchester. It is due to be completed and in operation by mid-1960 and will be engineered and constructed by Humphreys & Glasgow Ltd., of London.

Blaw Knox Ltd. announce the formation of a new affiliated company, Blaw Knox Chemical Engineering Co. Ltd., with registered offices at 90/94 Brompton Road, London, S.W.3. The new company is owned jointly by Blaw Knox of London and their associates, Blaw-Knox of Pittsburgh, Pa., U.S.A.

The formation of a new subsidiary company has been announced by Sir Clavering Fison, the chairman of the Fison Group of Companies. Fisons (Canada) Ltd. was formed in July of this year. The directors of the company include Mr. A. Wormald (commercial director of Fisons Ltd. and chairman of Fisons Pest Control Ltd.), Mr. W. Abel-Smith (Fisons Ltd.) and Prof. A. W. A. Brown (University of Western Ontario).

Chemical Construction (Great Britain) Ltd. will now be known as *Chemical Construction (G.B.) Ltd.*

Heat Exchangers Ltd. announce their change of address to 97 Tottenham Court Road, London, W.1.

F. A. Hughes & Co. Ltd. acquired new premises at 4 Stanhope Gate, London, W.1. Tel.: HYDe Park 6080.

The board of directors of Pfizer Ltd., in a statement issued by its chairman (Mr. Richard C. Fenton), announce the acquisition of the firm of Kemball, Bishop & Co. Ltd.

People in the News

The Lord President of the Council for Scientific and Industrial Research has appointed **Vice-Admiral Sir Frank Mason,** K.C.B., to be a member of the Council for Scientific and Industrial Research. Sir Frank is a director of Metal Industries Ltd. and H. W. Kearns & Co. Ltd. and is a consultant to Metropolitan-Vickers Electrical Co. Ltd. He was appointed chairman of the Mechanical Engineering Research Board last June. Before his retirement from the Royal Navy in 1957, he was Engineer-in-Chief of the Fleet.

The Council for Scientific and Industrial Research in South Africa has announced the appointment of **Dr. P. C. Carman** as director of the National Chemical Research Laboratory. Dr. Carman succeeds **Dr. W. S. Rapson,** who recently became vice-president of the C.S.I.R.

Dr. Carman was born in New Zealand and graduated with the Master of Science degree in chemistry and mathematics at the University of Otago in 1930. He moved to University College, London, where he was awarded the Ph.D. degree in 1934. Shortly afterwards, he received an appointment in the Research Division of Imperial Chemical Industries Ltd. to work on new processes for the manufacture of nitric and sulphuric acids. He was appointed principal research officer in the C.S.I.R. in 1947 to work with Dr. Rapson, who was at the time setting up the National Chemical Research Laboratory.

At the annual general meeting of the British Standards Institution, **Mr. R. E. Huffam**, United Kingdom co-ordinating director of Unilever Ltd. and chairman of B.S.I.'s Finance Committee since 1952, was elected as the Institution's new president.

The Council of the Association of British Chemical Manufacturers for 1958-9 is as follows: *president:* **Sir Walter Worboys** (I.C.I. Ltd.); *vice-presidents:* **Dr. F. H. Carr, Sir Roger Duncalfe, Dr. E. V. Evans, Sir Graham Hayman** (The Distillers Co. Ltd.), **Sir Harry Jephcott** (Glaxo Laboratories Ltd.), **Mr. C. F. Merriam, Mr. L. P. O'Brien** (Laporte Chemicals Ltd.), **Mr. G. F. Williams** (The British Drug Houses Ltd.); *elected members: chairman:* **Mr. B. Hickson** (Hickson & Welch Ltd.); *vice-chairman:* **Sir William Garrett** (Monsanto Chemicals Ltd.); *hon. treasurer:* **Mr. J. L. Harvey** (The Fullers' Earth Union Ltd.); **Mr. G. H. Beeby** (British Titan Products Co. Ltd.), **Mr. D. J. Bird** (Fisons Ltd.), **Mr. I. V. L. Fergusson** (Evans Medical Supplies Ltd.), **Mr. J. C. Hanbury** (Allen & Hanburys Ltd.), **Mr. R. S. Haskew** (The General Chemical & Pharmaceutical Co. Ltd.), **Dr. W. G. Hiscock** (Imperial Smelting Corporation Ltd.), **Mr. L. G. Matthews** (Burroughs, Wellcome & Co.), **Mr. F. S. Poole** (Peter Spence & Sons Ltd.), **Mr. H. V. Potter** (Bakelite Ltd.), **Mr. E. Stein** (The Distillers Co. Ltd.), **Dr. J. E. Taylor** (Joseph Crosfield & Sons Ltd.), **Mr. R. C. Todhunter** (I.C.I. Ltd.), **Mr. B. White** (A. Boake, Roberts & Co. Ltd.); *co-opted members:* **Mr. E. L. Bush** (W. J. Bush & Co. Ltd.), **Mr. G. H. W. Cullinan** (Shell Chemical Co. Ltd.), **Mr. M. J. C. Hutton-Wilson** (Associated Chemical Companies Ltd.), **Mr. J. H. Townsend** (I.C.I. Ltd.); *hon. vice-presidents:* **Mr. C. E. Carey** (South Eastern Gas Board), **Lord McGowan** (I.C.I. Ltd.), **Mr. K. H. Wilson;** *director:* **Mr. George Brearley;** and *general secretary:* **Mr. A. J. Holden.**

Mr. Richard Turner has been appointed a managing director of Johnson, Matthey & Co. Ltd. He relinquishes his position of managing director of Mallory Metallurgical Products Ltd., a sub-

BCS 4264 for further information

Hands off the H_2SO_4!

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sidiary company, but remains a director.

Mr. H. E. Cooper has been appointed managing director of G. A. Harvey & Co. (London) Ltd. Mr. Cooper, first appointed to the board in 1946, has been acting as deputy managing director since May of this year. Mr. I. A. Marriott succeeds Mr. P. T. Bliss as sales director. Mr. Bliss, who has been with the company for 50 years, retires on December 31.

The new company formed by Imperial Chemical Industries Ltd. and Celanese Corporation of America will initially be known as the Lindum Fibres Corporation. The board of the new company has been constituted as follows: From Celanese Corporation of America: **J. H. Black** (president), **Dr. R. T. Armstrong, J. W. Brooks** and **G. H. Richards.** From I.C.I.: **E. A. Bingen, Dr. A. Caress, Dr. E. D. Kamm** and **C. I. Rutherford.** Mr. E. A. Bingen is the I.C.I. director responsible for I.C.I.'s interests in the Western Hemisphere and Africa; Dr. Caress is the chairman of I.C.I.'s Fibres Division; and Dr. Kamm and Mr. Rutherford are directors of that Division.

Mr. R. C. Agabeg has been appointed assistant sales manager of the Chemicals Division of Union Carbide Ltd. He was formerly employed with the Sales Development Group of Monsanto Chemicals Ltd.

Babcock & Wilcox Ltd. announce the appointment of **Mr. J. H. Prole** as assistant manager of the company's mechanical handling division.

The appointment of **A. P. Gagnebin** as a vice-president and **J. M. Weldon** as an assistant vice-president of The International Nickel Co. Inc. has been announced.

George Kent Ltd. announce the recent appointment to the board of their Belgian subsidiary company, Kent-Continental S.A., of **Mr. F. J. Havenith** as local resident director. Mr. Havenith has been the manager, first of Kent's Brussels office and subsequently of the Belgian company, since its formation.

Mr. Peter Clark has joined Metal and Pipeline Endurance Ltd. as a senior corrosion engineer.

Mr. A. M. Hughes, general secretary of The Scientific Film Association, has been invited to become visual aids officer of the British Association for the Advancement of Science.

Meetings of the Month

Society of Chemical Industry

December 4. *Chemical Engineering Group:* At the Chemical Department, University of Bristol, Woodlands Road, Bristol. "Titanium and its Alloys as Materials of Construction for Chemical Plant", by Dr. K. W. Bowen. **6 p.m.**

December 9. *Chemical Engineering Group:* At the Society of Chemical Industry, 14 Belgrave Square, London, S.W.1. "Some Aspects of Radiation Induced Chemical Processes", by Dr. R. Roberts. **6 p.m.**

Institution of Chemical Engineers

November 19. *Midlands Branch:* At the Birmingham College of Technology, Gosta Green, Birmingham. "Chemical Engineering Aspects of Tar Acid Recovery", by D. McNeil. **6.30 p.m.**

November 19. *North-western Branch:* At the Chemistry Department Lecture Theatre, The University, Leeds, 2. "Electro-chemical Aspects of Corrosion", by G. L. Lennard. **7 p.m.**

November 21. *London Centre of the Graduates and Students Section:* At Caxton Hall, Westminster, London, S.W.1. "Analytical Instruments for Process Use", by J. D. Tallentire. **5.30 p.m.**

November 25. *South Wales and Monmouthshire Group:* At the South Wales Institute of Engineers, Park Place, Cardiff. "The Use of Fluidised Processes in Iron and Steel Manufacture", by S. A. Gregory. **7.15 p.m.**

November 25. *London:* At the Geological Society, Burlington House, London, W.1. "A Suggested Equation Relating to the Mixing of Powders and its Application to the Study of the Performance of Certain Types of Machine", by H. E. Rose. **5.30 p.m.**

November 25. *North-western Branch:* At the Birkenhead Technical College, Birkenhead. "Pollution Law and the Chemical Engineer", by R. R. Ferner. **7 p.m.**

November 28. *Scottish Group:* At the Royal College of Science and Technology, Glasgow. "The Measurement and Significance of Residence-time Distribution", by Prof. P. V. Danckwerts. **7 p.m.**

December 2. *North-western Branch:* At the Chemical Engineering Building, Manchester College of Science and Technology, Jackson Street, Manchester. "Wetted Area in Packed Towers", by W. S. Norman and B. Solomon. **6.30 p.m.**

December 5. *London Centre of the Graduates and Students Section:* At Caxton Hall, Westminster, London, S.W.1. "The Function of the Design Problem in Chemical Engineering Education", by W. S. Norman. **6.30 p.m.**

December 10. *Midlands Branch:* At the Birmingham College of Technology, Gosta Green, Birmingham. "Chemical Engineering as Applied to the Manufacture of Antibiotics", by J. Stuart. **6.30 p.m.**

December 17. *London Branch:* At the Geological Society, Burlington House, London, W.1. "Liquid Distribution in Grid Packings", Parts I and II, by J. W. Mullin. **5.30 p.m.**

British Nuclear Energy Conference

November 26. At the Institute of Marine Engineers, 76 Mark Lane, London, E.C.3. Sir Charles Parsons Memorial Lecture 1958, "Recent Advances in Nuclear Engineering", by Sir John Cockroft. **5.30 p.m.**

December 5. At the Institution of Mechanical Engineers, Birdcage Walk, London, S.W. 1."An Experimental Investigation into the Stress Distribution in a Band Reinforced Pressure Vessel", by K. G. Mantle, N. Marshall and P. J. Palmer. **6 p.m.**

Institution of Civil Engineers

December 9. At Great George Street, Westminster, London, S.W.1. "The Use of Radioactive Isotopes for the Investigation of Sewage Treatment Plant", by S. G. Burgess and A. F. Green. **5.30 p.m.**

Institution of Mechanical Engineers

December 19. At 1 Birdcage Walk, Westminster, London, S.W.1. Ordinary Meeting. James Clayton Lecture "The Hydraulic Turbine in Evolution", by M. P. Danel. **6 p.m.**

Institute of Petroleum

December 3. At 61 New Cavendish Street, London, W.1. "Flow Properties of Distillates at Low Temperatures: A Review", by J. F. Hutton. "Pumpability of Aviation Turbine Fuels at Low Temperatures", by Hugh Strawson. **5.30 p.m.**

Physical Society

December 18. At Cavendish Laboratory, Cambridge. Conference on Solid State Physics, entitled "Interfacial Phenomena", **until December 20.**

November 28. In London. The 1958 Rutherford Lecture will be delivered by Professor Neils Bohr.

Institute of Refrigeration

December 4. At the Institute of Marine Engineers, The Memorial Building, 76 Mark Lane, London, E.C.3. A Review of the Moscow Meetings of the International Institute of Refrigeration. **5.30 p.m.**

Scientific Film Association

December 9. At the Mullard Theatre, Mullard House, Torrington Place,, London, W.C.1. "Presenting Science and Technology to Specialist and Layman—The Contribution of Film". This programme of varied film illustrations will be supplemented by a demonstration of stereophonic sound equipment. This meeting is open to members of the S.F.A., the Royal Photographic Society and the British Film Academy. **8 p.m.**

Society of Instrument Technology

November 19. *Newcastle Section:* At King's College, Stephenson Buildings, Newcastle upon Tyne. "Flow Measurement with Particular Reference to the Dall Tube", by D. H. Kent. **7 p.m.**

November 26. *Chester Section:* At Grosvenor Museum, Chester. "Instrumentation in Chemical Analytical Control", by B. W. Bradford. **7 p.m.**

December 2. *Cheltenham Section:* At The Rotunda, Cheltenham. "The Industrial Uses of Computers", by R. H. Tazard. **7.30 p.m.**

December 5. *Fawley Section:* At Copthorne House, Fawley, Hants. "Electrical Weighing, its Techniques and Application", by K. J. Railler.

Coming Events

Home

November 24. *Symposium on "The Mechanisation of Thought Processes":* At the National Physical Laboratory, Teddington, Middlesex, **until November 27.**

November 28. *Electronic Computer Symposium and Exhibition:* At Olympia, London, **until December 4.**